ILLINOIS
STATE GEOLOGICAL SURVEY

STATE OF ILLINOIS
DEPARTMENT OF REGISTRATION AND EDUCATION

DIVISION OF THE
STATE GEOLOGICAL SURVEY
FRANK W. DeWOLF, Chief

BULLETIN NO. 36

YEAR BOOK FOR 1916

ADMINISTRATIVE REPORT
AND
ECONOMIC AND GEOLOGICAL PAPERS

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FRANK W. DeWOLF, *Chief*

LETTER OF TRANSMITTAL

State Geological Survey Division, Nov. 19, 1919.

Francis W. Shepardson, Chairman, and Members of the Board of Natural Resources and Conservation,

Gentlemen:—I submit herewith my administrative report for the fiscal year ended June 30, 1917, accompanied by a statistical report for the calendar year 1916, a report on clay deposits of unusual interest, and a study of the La Salle anticline which will prove valuable not only to students of the science, but to those interested in geology from an economic standpoint as well.

One of the papers, that on Mountain Glen clay deposits, has appeared as an extract from this bulletin, but the others are published for the first time.

Very respectfully,

Frank W. DeWolf, *Chief.*

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By F. W. DeWolf, Director

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General Statement

During the fiscal year 1916-1917 the Geological Survey made a great many investigations of the geology of various sections of the State and did a large amount of work on matters of economic importance, includ-

ing coal, oil and gas, clay, and other non-metallic minerals. A large area was mapped topographically in cooperation with the United States Geological Survey, as described on the following pages.

Although a change in State administration occurred during the year, the Survey continued to be under the direction of the same Commissioners, and there was no interruption to the program laid out at the beginning of the year. Toward the close of the year preliminary steps toward a reorganization of the activities under the provisions of the Code were made, but it was decided that the nature of Survey work and the scope and form of publications should remain the same as in the past.

Organization and Personnel

The Survey is informally subdivided into a general office section and three technical sections—Geologic, Topographic, and Mining Investigations. The topographic work was carried on as formerly, in cooperation with the U. S. Geological Survey and under the immediate direction of Mr. R. B. Marshall, Chief Geographer of that organization. There was no sharp line between the work of the Geologic Section and the section on Mining Investigations, because in both cases the work was essentially geological in character. This section was administered by F. W. DeWolf, Director, and F. H. Kay, Assistant Director, until the time of the latter's resignation in May. The work of the Mining Investigations was similarly directed by Mr. DeWolf, in accordance with a joint program approved by representatives of the University of Illinois and of the United States Bureau of Mines. The latter organization maintained offices at Urbana, as headquarters for mining engineers engaged in the Cooperative work.

Miss Carrie H. Thory acted as chief clerk of the Survey assisted by Miss Faith Neighbour as stenographer and clerk. The technical files and the work of editing were assigned to Miss Helen Skewes, geologist, and after her resignation, to Miss Nellie Barrett.

Professors Salisbury, Grant, and Barrows continued to serve as consulting geologists, and Professors Parr and Bartow as consulting chemists. Mr. R. K. Hursh, of the Ceramics Department, University of Illinois, advised with the Director regarding investigations of ceramic materials.

In addition to the services of Professors Weller, Savage, and Barrows, which were continued, a considerable number of new men were engaged for part-time work during the summer periods. A full list of the men comprising the Survey organization for the year is given below:

COMMISSIONERS

Governor Frank O. Lowden, Chairman
Professor T. C. Chamberlin, Vice-Chairman
President E. J. James, Secretary

GENERAL OFFICE SECTION

F. W. DeWolf, Director
Fred H. Kay, Assistant State Geologist
Carrie H. Thory, Chief Clerk
Helen Skewes, Geologic Clerk
Nellie Barrett, Geologic Clerk
Faith Neighbour, Stenographer
W. G. Gwynn, Draftsman
W. S. Nelson, Draftsman
W. B. Walraven, Draftsman
Marian Ream, Draftsman

GEOLOGIC AND MINING INVESTIGATIONS SECTION

F. W. DeWolf, Geologist
R. D. Salisbury, Consulting Geologist
U. S. Grant, Consulting Geologist
Harlan H. Barrows, Consulting Geologist
S. W. Parr, Consulting Chemist
Edward Bartow, Consulting Chemist
R. K. Hursh, Consulting Ceramist
Stuart Weller, Geologist
T. E. Savage, Geologist
Fred H. Kay, Geologist
G. H. Cady, Geologist
A. D. Brokaw, Geologist
Stuart St. Clair, Geologist
Charles Butts, Geologist (U. S. G. S.)
C. B. Anderson, Geologist
Merle L. Nebel, Geologist
L. E. Young, Mining Engineer
H. F. Crooks, Assistant Geologist
E. F. Rehnquist, Field Assistant
Other short-time assistants in field and office

Cooperation

Formal cooperation with the U. S. Geological Survey in the topographic work and in the collection of mineral statistics has been maintained. Cooperation on quadrangle surveys has been largely abandoned, temporarily it is hoped, but Mr. Charles Butts has during the past year

made investigations under a joint agreement. The U. S. Bureau of Mines and the Engineering Experiment Station of the University of Illinois continue to cooperate with the Geological Survey in a study of coal resources and technical problems relating to the safe and efficient operation of coal mines. Various laboratories of the University of Illinois are available for the work of Survey investigators, and the coal laboratory and the ceramics laboratory are conveniences which are highly appreciated.

GEOLOGICAL SECTION

General Stratigraphy

Stratigraphic studies of the Mississippian formations in southern Illinois were continued by Professor Weller, and some detailed mapping was done on the Golconda and Brownfield quadrangles. A field conference on matters in dispute was attended by Messrs. Ashley, Ulrich, Girty, and Butts of the U. S. Geological Survey, and by Professor Weller and Mr. DeWolf of the State Survey. Examinations of field evidence extended from Monroe County through Randolph, Union, Johnson, Pope, and Hardin counties, and to Hopkinsville, Kentucky, where a final conference was held and a tentative agreement on most points was reached.

Studies of stratigraphy were of course included in connection with economic investigations mentioned under the following headings, but attention should be called to continuation of a detailed examination of the La Salle anticline by Mr. Cady, involving as it did both the general stratigraphy and structure of the area through which the anticline passes. Study of underground stratigraphy was also made by C. B. Anderson, in connection with his investigation of artesian water resources of northeastern Illinois. This report was made ready for printing.

Coal

A large amount of the work dealing distinctly with coal has been carried on by the Illinois Coal Mining Investigations under a cooperative agreement between the State Geological Survey, the U. S. Bureau of Mines, and the Engineering Experiment Station of the University of Illinois. A report on coal resources of Saline and Gallatin counties was completed by Mr. Cady. Field work was finished for a similar report on northwestern Illinois, and a bulletin on Jackson County and vicinity was published during the year. A study of surface subsidence due to coal mining, by L. E. Young, was published. Besides these specific coal reports, investigation of coal resources was made also in connection with the quadrangle surveys which are described in a following paragraph.

Oil and Gas

Production of petroleum for the calendar year 1916 totaled 17,714-235 barrels, with a value of $29,237,168, as compared with 19,041,695 barrels in 1915, with a value of $18,655,850. Because of the growing decline in production and the advanced price which warranted further exploration, more work than usual was done in an effort to find promising areas for development. Mr. Kay took general charge of this work. The promising structure extending through Gallatin, Saline, Williamson, Pope, Johnson, and Union counties, together with an area on the west, was studied in reconnaissance fashion by Albert D. Brokaw and Stuart St. Clair. Bulletins on these areas were published early in the year, and other oil papers were issued in Bulletin No. 35. During the year oil was discovered on the Irishtown anticline in Clinton County, which had been recommended in an earlier bulletin.[1]

Clay

A report on clays available in coal mines of the State was published under the authorship of R. T. Stull and R. K. Hursh.

Educational Bulletins

The preparation of the "Geography of Illinois" by Professors Salisbury and Barrows made considerable progress during the year, but is still far from complete. A related matter, the Starved Rock bulletin, in preparation of which the Survey cooperated with the Geographic Society of Chicago, was made ready for printing. This includes a chapter by Mr. Cady, and topographic and geologic maps furnished by the Survey. Bulletin 27, on "Geography of the Upper Illinois Valley", by Carl O. Sauer, was published during the year.

Quadrangle Surveys

Certain quadrangles were surveyed and reports prepared on a cooperative program with the U. S. Geological Survey. Reports on Hardinville, Birds, and Vincennes quadrangles were published in Bulletin 33. A manuscript for the report on the Baldwin and Coulterville quardangles was practically completed; the Ottawa and Marseilles quadrangles were partly surveyed. The Federal Survey published the Galena-Elizabeth folio, and made progress on others submitted to them for publication in cooperation.

Late in the year it was possible to undertake a survey of the Edging-

[1] Blatchley, R. S., Oil and gas in Bond, Macoupin, and Montgomery counties, Illinois: Ill. State Geol. Survey Bull. 28, pp. 45-46 1914.

TABLE 1.—*Progress of field work by the topographic section*

Quadrangles	Counties	Pubi-cation scale	Area mapped	Levels		Traverse		
				Primary	Perm. B. M's.	Primary	Perm. marks	Second-ary
			Sq. mi.	*Miles*		*Miles*		*Miles*
Vienna	Johnson, Massac, Pulaski	1:62,500	99	..	..	..	..	412
Vermont	McDonough	1:62,500	37	..	..	51	4	187
Goodhope	McDonough, Warren	1:62,500	75	..	..	..	..	332
La Harpe	Henderson, Warren, Hancock, McDonough	1:62,500	227	..	..	..	..	1,029
Dixon	Lee, Ogle	1:62,500	223	106	29	..	..	105
Wilmington	Will, Kankakee	1:62,500	19	..	..	..	..	..
Campbell Hill	Randolph, Perry, Johnson	1:62,500	41	..	..	..	..	110
Dongola	Union, Johnson, Pulaski	....	..	..	..	112	3	..
Oregon	Ogle	....	..	16	..	..	..	..
	Totals		721	122	29	163	7	2,175

ton quadrangle, in Rock Island and Mercer counties; of the Goodhope and LaHarpe quadrangles, in Warren, McDonough, Henderson and Hancock counties; and of the Golconda and Brownfield quadrangles, in Johnson, Pope, and Massac counties.

Mineral Statistics

The Survey has continued to cooperate with the U. S. Geological Survey in the collection of mineral statistics, and the results for the year 1916 are given on a later page.

Bureau of Information

The Survey maintains a bureau of information for the convenience of inquirers about mineral resources of Illinois. Requests are received in great numbers, both from inside and outside the State. When possible, a bulletin containing the desired information is mailed. Frequently, however, it is necessary to make special study and to reply by letter at some length. Many requests for the identification of minerals are received and answered promptly; others for chemical analysis of specimens are, for the most part, necessarily refused. It has been found that the collection of a representative sample of a material and the investigation of its favorable occurrence for development are quite as essential and require expert advice, just as does chemical analysis. As a rule, therefore, unless a representative of the Survey investigates and samples a mineral deposit, an analysis at public expense is not justified, particularly because otherwise Survey funds would be seriously depleted by work which frequently is of no permanent value. Preliminary examinations and opinions as to probable value of minerals are always cheerfully given.

TOPOGRAPHIC SECTION

In accordance with the cooperative agreement, the Commissioners allotted $9,000 for the continuation of cooperative topographic surveys, and the United States Geological Survey allotted an equal amount. The survey of the Vienna, Vermont, Goodhope, La Harpe, and Dixon quadrangles and of the Illinois portion of the Campbell Hill quadrangle, in Johnson, Massac, Pulaski, McDonough, Warren, Henderson, Hancock, Randolph, Lee, and Ogle counties, was completed by J. A. Duck, L. B. Glasgow, M. A. Roudabush, Gilbert Young, L. L. Lee, C. W. Goodlove, Ralph Wilcoxon, R. L. Harrison, and F. W. Hughes. The area mapped totaled 702 square miles, all to be published on the scale of 1:62,500, with a contour interval of 20 feet. The resurvey of the Wilmington quadrangle, in Will and Kankakee counties, was completed by Mr. Har-

rison, the area mapped being 30 square miles, for publication on the scale of 1:62,500, with a contour interval of 20 feet. For the control of the Vermont and Dongola quadrangles, in Fulton, McDonough, Schuyler, Union, Johnson, and Pulaski counties, J. H. Wilson ran 163 miles of primary traverse and set 7 permanent marks. For the control of the Dixon and Oregon quadrangles, in Lee and Ogle counties, H. S. Senseney ran 122 miles of primary levels and established 29 permanent bench marks.

PUBLICATIONS

Reports

The past year has broken all records for publication because of greater freedom gained by an ample appropriation made direct to the Commission. As result, previous delays in printing have been overcome, and excellent work has been obtained. Reports were issued as follows:

Extract from Bulletin 35: Preliminary oil report on southern Illinois.
Bulletin 32: Report and plans for reclamation of land subject to overflow in the Spoon River valley.
Bulletin 27: Geography of the upper Illinois valley.
Bulletin 35: Oil investigations in Illinois in 1916.
Bulletin 33: Year book for 1915.
Extract from Bulletin 36: Clay deposits near Mountain Glen, Union County, Illinois.
Bulletin 23: Biennial report for 1911 and 1912.
Bulletin 30: Biennial report for 1913 and 1914.
Cooperative Bulletin 3: Chemical study of Illinois coals.
Cooperative Bulletin 15: Coal resources of District VI.
Cooperative Bulletin 17: Surface subsidence in Illinois coal mines.
Cooperative Bulletin 18: Tests on clay materials available in Illinois coal mines.
Cooperative Bulletin 16: Coal resources of District II.

The distribution of these reports so as to prevent waste, and yet make them most widely available, has been in itself a considerable task. It is thought that the interests of all concerned would be best met if 500 copies of each report were reserved for sale at the cost of printing, the receipts from the sales being turned into the State treasury. This makes it possible for libraries to complete their sets and for persons having real need for any of the volumes to obtain the earlier ones at small cost. The remainder of the edition is distributed by the Survey and the Secretary of State to institutions and individuals making application for them, or is exchanged with other Surveys or publishing organizations.

Any of the published reports will be sent upon receipt of the amount noted. Money orders, drafts, and checks should be made payable to F. W. DeWolf, Chief.

Maps

During the year numerous illustrations were prepared for various bulletins, and the following larger maps were published:

Topographic maps of Monroe, Clinton, Lawrence, and Hardin counties.

State coal field and coal mine map.

The revised geological map was in press at the end of the year.

EXPENDITURES

The total expenditures for the period from July 1, 1916 to June 30, 1917, were as follows:

Table 2.—*Total expenditures July 1, 1916 to June 30, 1917*

General appropriation—		
Balance on hand July 1, 1916	$ 7,817.52	
Appropriation July 1, 1916	32,690.00	
Total available	....	$40,507.52
Expenditures July 1, 1916 to June 30, 1917—		
Salary and expenses of administration	6,697.98	
Clerical help and general office expenses	6,088.08	
Equipment for new offices	2,354.07	
Equipment for field work	1,136.17	
Postage for distribution of bulletins	802.11	
Oil Investigations	3,877.33	
Coal Investigations (subsidence)	1,418.22	
Cooperative geological surveys	770.76	
General stratigraphic studies	1,228.54	
Water resources investigations	320.99	
Clay resources investigations	140.00	
Geological surveys (quadrangles)	739.23	
Structural geology	575.37	
Educational series	1,823.22	
Statistics	372.75	
Miscellaneous	346.50	
Topographic surveys	8,791.14	
Printing and binding	1,415.78	38,898.24
Balance available July 1, 1917	....	$ 1,609.28
Appropriation for engraving and lithographing maps and illustrations—		
Balance on hand July 1, 1916	$2,127.67	
Appropriation July 1, 1916	2,500.00	
Total available	....	$4,627.67
Expended July 1, 1916 to June 30, 1917	....	2,229.02
Balance available July 1, 1917	....	$2,398.65

TABLE 2—Concluded

Appropriation for printing and binding—		
Balance on hand July 1, 1916	$3,022.80	
Appropriation July 1, 1916	6,500.00	
Total available	....	$9,522.80
Expended July 1, 1916 to June 30, 1917	....	9,522.80
Balance available July 1, 1917	....	....

MINERAL RESOURCES IN ILLINOIS IN 1916

By N. O. Barrett

OUTLINE

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INTRODUCTION

Acknowledgments

The mineral statistics for Illinois in 1916 were collected by the U. S. Geological Survey and the Illinois State Geological Survey in cooperation. Many of the figures used in this report were taken from the compilations published by the Federal Survey in its 1916 report on "Mineral Resources of the United States". To individual members of the Survey

who willingly rendered considerable assistance, especially in the compilation of certain tables from the original statistics, acknowledgments are also due.

TABLE 3.—*Comparison of values of total mineral production in Illinois with those of total agricultural products, 1905-1916*

Year	Mineral production	Agricultural production	Ratio of values of mineral to agricultural production
			Per cent
1905	$ 68,025,560	$272,794,107	24.9
1906	72,723,572	253,409,404	28.7
1907	93,539,464	280,666,020	33.3
1908	92,765,688	276,614,637	33.5
1909	98,840,729	322,144,944	30.7
1910	98,891,759	297,976,709	33.2
1911	106,275,115	311,525,706	34.1
1912	123,068,867	285,249,557	43.2
1913	131,825,221	288,613,140	45.9
1914	117,145,108	289,781,140	40.4
1915	114,704,587	486,561,355	23.5
1916	146,780,236	496,178,000	29.6

General Review

For abundant mineral resources one is not usually inclined to look to a State of richly productive farm lands like those of Illinois, with their flat prairies and thick soils deeply burying all signs of solid rock in most places. But, fourth in production of petroleum, limestone, and clay products; third in brick and tile, as well as in coal production; and leader in the fluorspar, sand and gravel, and tripoli industries, Illinois presents excellent proof that agricultural wealth does not necessarily entail mineral poverty.

Though agriculture is and doubtless always will be the dominant feature of Illinois' economy, it is clear that the mineral industries are gradually gaining in relative importance, in spite of the fluctuations brought out in Table 3. As compared with other states, Illinois ranked high in 1916 in total value of mineral production, Pennsylvania and West Virginia being the only states that reported greater production. A comparison of the productions for the past two years shows a highly gratifying increase of 28 per cent for 1916 as compared with 1915. Table 4 shows the value of Illinois products from 1907 to 1916. Table 5 shows the products of, and total mineral values for, each of the counties in the State during 1916.

TABLE 4.—*Output and value of mineral products in Illinois, 1907-1916*

Product	1907		1908		1909		1910		1911	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Asphalt....short tons	...	...	...	...	...	...	...	...	(c)	(c)
Briquets....short tons	...	...	...	...	...	...	...	...	(b) (c)	(b) (c)
Cement....barrels	a2,036,093	a$2,632,567	a3,211,168	a$2,707,044	a4,241,392	a$3,388,667	a4,459,450	a$4,119,012	a4,582,341	a$3,583,301
Clay products....	...	13,220,489	...	11,559,114	...	14,344,453	...	15,176,161	...	14,333,011
Clay, raw....short tons	b123,775	b105,703	b117,082	b114,482	b144,060	b150,868	b188,803	b190,896	b182,836	b183,826
Coal....short tons	51,317,146	54,687,382	47,659,690	49,978,247	50,904,990	53,522,014	45,900,246	52,405,897	53,679,118	59,519,478
Coke....short tons	372,697	b1,737,464	362,182	b1,538,952	1,276,956	b5,361,510	1,514,504	b6,712,550	1,610,212	b6,390,251
Ferro-alloys....long tons	...	...	...	...	...	...	...	...	(b) (c)	(b) (c)
Fluorspar....short tons	25,128	141,971	31,727	172,838	41,852	232,251	47,302	277,764	68,817	481,635
Iron, pig....long tons	2,457,768	b52,229,000	1,691,944	b30,135,000	2,467,156	b44,211,000	2,675,646	b42,917,362	2,036,081	b31,152,927
Lead....short tons	498	52,788	363	30,492	273	23,478	262	23,056	964	86,760
Lime....short tons	124,784	559,305	92,549	393,951	104,260	454,682	113,239	503,581	92,169	423,762
Mineral paints, zinc and lead pigments....	...	(c)	...	(c)	...	(c)	...	(c)	...	(c)
Mineral waters....gallons sold	720,400	91,760	685,763	58,904	639,460	49,108	1,117,620	83,148	1,304,950	82,330
Natural gas....	...	143,577	...	446,077	...	644,401	...	613,642	...	687,726
Petroleum....barrels	24,281,973	16,432,947	33,685,106	22,648,881	30,898,339	19,788,864	33,143,362	19,669,383	31,317,038	19,734,339
Pyrite....long tons	(c)	(c)	(c)	(c)	5,600	17,551	8,541	28,159	17,441	47,020
Sand and gravel....short tons	4,550,991	1,367,653	6,657,748	1,503,022	9,155,229	1,949,497	8,586,508	1,730,795	8,488,683	1,990,922
Silver....fine ounces	2,900	1,900	2,000	1,100	900	500	2,000	1,100	3,036	1,609
Stone....	...	3,789,342	...	3,134,770	...	4,261,818	...	3,853,425	...	3,467,930
Sulphuric acid d(60° Baume)....short tons	...	...	...	...	...	...	...	...	144,805	958,591
Tripoli....	...	(c)	...	(c)	...	39,262	...	33,390	...	45,910
Zinc....short tons	1,446	170,628	298	28,012	675	72,900	351	167,508	4,219	480,966
Miscellaneous....	...	247,146	...	103,236	...	51,283	...	1,720,002	...	1,199,475
Total....	$93,539,464		$92,765,688		$98,840,729		$98,891,759		$106,275,115	

[a] Exclusive of natural cement, value for which is included under "Miscellaneous."
[b] Value not included in "Total."
[c] Value included under "Miscellaneous."
[d] From zinc smelting.

Product	1912 Quantity	1912 Value	1913 Quantity	1913 Value	1914 Quantity	1914 Value	1915 Quantity	1915 Value	1916 Quantity	1916 Value
Asphalt.........short tons	(c)	(c)	(c)	(c)	41,553	$340,862	188,575	$1,041,378	155,406	$1,285,470
Briquets.........short tons	(b) (c)	(c) (c)	....	....	....	....	....	....	....	....
Cement.........barrels	[a]4,602,617	[a]$3,444,085	[a]4,734,540	[a]$ 4,784,696	[a]5,284,022	[a]4,848,522	[a]5,435,655	[a]4,884,026	[a]3,562,659	[a]3,386,431
Clay products.........	....	15,210,990	....	15,195,874	....	13,318,953	....	14,791,938	....	17,633,351
Clay, raw.........short tons	[b]176,558	[b]192,663	[b]194,937	[b]204,037	[b]161,084	[b]168,354	[b]163,904	[b]169,320	[b]197,701	[b]378,440
Coal.........short tons	59,885,226	70,294,338	61,618,744	70,313,605	57,589,197	64,693,529	58,829,576	64,622,471	66,195,336	82,457,954
Coke.........short tons	1,764,944	[b]8,069,903	1,859,553	[b]8,593,581	1,425,168	[b]5,858,700	1,686,998	[b]7,016,635	2,320,400	[b]10,619,066
Ferro-alloys.........long tons	(b) (c)	(b) (c)	(b) (c)	(b) (c)	(b) (c)	(b) (c)	(b) (c)	(b) (c)	(b) (c)	(b) (c)
Fluorspar.........short tons	114,410	756,653	85,854	550,815	73,811	426,063	(c)	(c)	(c)	(c)
Iron, pig.........long tons	2,806,378	[b]42,828,816	2,892,263	[b]45,796,966	1,793,714	[b]24,382,458	2,455,894	[b]34,207,901	3,857,391	[b]67,764,309
Lead.........short tons	1,282	115,380	959	84,392	717	55,926	954	89,676	1,072	147,936
Lime.........short tons	98,450	394,892	95,977	433,331	87,603	362,727	88,604	352,954	80,012	369,038
Mineral paints, zinc and lead pigments...	....	(c)	....	(c)	....	(c)	....	(c)	....	(c)
Mineral waters.........gallons sold	1,143,625	74,445	1,216,442	68,549	1,760,030	81,307	1,559,489	75,290	1,777,741	94,056
Natural gas.........	....	616,467	....	574,015	....	437,275	....	350,371	....	396,357
Natural gasoline.........gallons sold	....	....	581,171	[b]67,106	1,164,178	[b]100,331	1,035,204	[b]80,049	2,260,288	[b]262,664
Petroleum.........barrels	28,601,308	24,332,605	23,893,899	30,971,910	21,919,749	25,426,179	19,041,695	18,655,850	17,714,235	29,237,168
Pyrite.........long tons	27,008	62,980	11,246	31,966	22,538	59,079	14,849	22,476	20,482	51,432
Sand and gravel.........short tons	6,957,901	1,929,822	7,992,140	2,070,491	7,696,130	1,859,519	7,708,012	1,984,569	8,365,225	2,587,437
Silver.........fine ounces	4,731	2,909	3,541	2,139	2,112	1,168	3,864	1,959	5,684	3,740
Stone.........	....	3,841,504	....	4,140,953	....	2,934,078	....	2,907,410	....	3,403,094
Sulphuric acid [d](60° Baume)....short tons	160,378	1,064,564	195,145	1,303,986	243,457	1,551,876	....	2,036,311	....	2,999,548
Tripoli.........	....	27,339	....	128,892	....	59,394	....	59,390	....	82,968
Zinc.........short tons	4,065	560,970	2,236	250,432	4,811	490,722	5,534	1,372,432	3,404	912,272
Miscellaneous.........	....	1,992,632	....	1,756,126	....	1,272,055	....	2,261,215	....	5,435,453
Total.........	$123,068,867		$131,825,221		$117,145,108		$114,704,587		$146,780,236	

[a] Exclusive of natural cement, value for which is included under "Miscellaneous."
[b] Value not included in "Total."
[c] Value included under "Miscellaneous."
[d] From zinc smelting.

TABLE 5.—*Products and total mineral values, by counties, 1916.*

County	Products (named in decreasing order of importance)	Total value
Adams	Lime, stone, clay products, sand and gravel	$ 245,228
Alexander	Stone, tripoli, sand and gravel	73,042
Bond	Coal, sand and gravel, natural gas	164,822
Boone	Clay products, stone, sand and gravel	16,805
Brown	Mineral water	(b)
Bureau	Coal, clay products, sand and gravel, natural gas	2,590,997
Calhoun	....	....
Carroll	Stone, sand and gravel	4,384
Cass	Clay products, sand and gravel	12,244
Champaign	Clay products, natural gas	38,360
Christian	Coal, clay products	2,853,668
Clark	Petroleum, natural gas, stone	[a]1,899,313
Clay	....	....
Clinton	Coal, petroleum, clay products	1,671,040
Coles	Petroleum	(b)
Cook	Clay products, stone, sand and gravel, lime	8,985,661
Crawford	Petroleum, natural gas, sand and gravel	[a]7,544,273
Cumberland	Petroleum, natural gas	[a]578,076
DeKalb	Sand and gravel	(b)
DeWitt	Clay products, natural gas	1,345
Douglas	Clay products	(b)
DuPage	Stone, clay products	103,431
Edgar	Clay products, petroleum, natural gas	11,516
Edwards	Clay products	247,168
Effingham	Clay products	(b)
Fayette	Clay products, sand and gravel	49,050
Ford	Sand and gravel	(b)
Franklin	Coal	12,590,987
Fulton	Coal, clay products, sand and gravel	3,248,003
Gallatin	Coal, clay products	136,973
Greene	Clay products, coal, clay, stone	282,176
Grundy	Coal, clay products, clay	734,359
Hamilton	Clay products	(b)
Hancock	Clay products, coal, sand and gravel	45,597
Hardin	Fluorspar, lead, stone, silver	826,241
Henderson	Sand and gravel	10,218
Henry	Coal, clay products, mineral water	93,087
Iroquois	Clay products	43,431
Jackson	Coal, clay products	1,169,102
Jasper	Petroleum	(b)
Jefferson	....	....
Jersey	Clay products, stone	54,449
Jo Daviess	Zinc, lead, stone	977,228
Johnson	Stone, coal	66,978
Kane	Sand and gravel, clay products, stone, mineral water	359,626
Kankakee	Clay products, stone, lime	860,861
Kendall	Sand and gravel, stone	38,356
Knox	Clay products, coal	1,295,405
Lake	Clay products, sand and gravel, mineral water	362,238
La Salle	Cement, coal, clay products, sand and gravel, clay, quartz, mineral water, stone	6,078,175
Lawrence	Petroleum, natural gas, clay products	[a]16,249,967
Lee	Cement, clay products, stone, sand and gravel, natural gas	1,366,911
Livingston	Clay products, coal, sand and gravel, clay	1,074,220
Logan	Coal, sand and gravel, clay products, natural gas	747,509
McDonough	Clay products, petroleum, clay, coal	1,311,448
McHenry	Clay products, sand and gravel, mineral water	482,151

TABLE 5.—*Products and total mineral values, by counties, 1916.*—Concluded.

County	Products (named in decreasing order of importance)	Total value
McLean	Coal, clay products, sand and gravel	216,196
Macon	Coal, clay products, sand and gravel	550,770
Macoupin	Coal, clay products, natural gas, petroleum	[a]6,062,259
Madison	Coal, clay products, stone, sand and gravel, lime, pyrite, mineral water, petroleum	5,072,510
Marion	Coal, petroleum, clay products	1,519,692
Marshall	Coal	860,547
Mason	Clay products	([b])
Massac	Clay products	([b])
Menard	Coal, clay products, sand and gravel	271,400
Mercer	Coal, clay products, sand and gravel	712,234
Monroe	Stone, sand and gravel	28,056
Montgomery	Coal, clay products	3,649,403
Morgan	Mineral water, clay products, petroleum, natural gas	62,203
Moultrie	Coal, clay products	263,283
Ogle	Sand and gravel, quartz, clay products, clay, stone	158,116
Peoria	Coal, sand and gravel, clay products, mineral water	1,846,858
Perry	Coal	2,744,198
Piatt	....	....
Pike	Stone, sand and gravel, natural gas, clay products, mineral water	43,655
Pope	Mineral water	([b])
Pulaski	Clay products	([b])
Putnam	Coal	1,047,053
Randolph	Coal, stone, sand and gravel, clay products	1,123,016
Richland	....	....
Rock Island	Sand and gravel, clay products, coal, lime, mineral water	267,423
Saline	Coal, clay products	5,008,100
Sangamon	Coal, clay products	6,604,211
Schuyler	Coal, clay products	20,230
Scott	Clay products, clay, coal	73,990
Shelby	Coal, clay products, sand and gravel	124,259
St. Clair	Coal, stone, clay products, sand and gravel	5,012,024
Stark	Coal, clay products	18,299
Stephenson	Stone, clay products	6,928
Tazewell	Coal, clay products, sand and gravel, mineral water	830,337
Union	Clay, tripoli, stone	299,365
Vermilion	Coal, clay products, stone, pyrite, sand and gravel	4,936,566
Wabash	Petroleum, sand and gravel	204,342
Warren	Clay products, coal	414,736
Washington	Coal, clay products	819,324
Wayne	....	....
White	Coal, clay products, sand and gravel	99,142
Will	Clay products, sand and gravel, stone, coal, lime	1,380,891
Whiteside	Sand and gravel, stone, clay products	38,670
Williamson	Coal, clay products	9,643,059
Winnebago	Sand and gravel, stone, lime	225,591
Woodford	Coal, clay products	345,192

[a] The figures for natural gas for certain counties have been estimated since some companies have no way of dividing the total figures into county units. An approximation of the values for Clark, Crawford, Cumberland, Lawrence, and Macoupin counties was made by dividing the totals for two different large companies into the proportion of the number of wells in each county.

[b] Concealed, fewer than three producers reporting production.

COAL

The value of the coal produced in Illinois in 1916 made up 14.9 per cent of the total value of the bituminous coal production for the United States and 45 per cent of the total value of the mineral production of the State. The increase of tonnage to 66,195,336 in 1916 represented an increase of 12.5 per cent over the 1915 production of 58,829,576 tons; and the increase in the value of output to $82,457,954 constituted an increase of 27.6 per cent over the 1915 value of $64,622,471. It is believed that if lack of cars and scarcity of labor had not interfered, the production would have been appreciably larger, for the demand strengthened notably during the latter half of the year. Offsetting the scarcity of labor to some

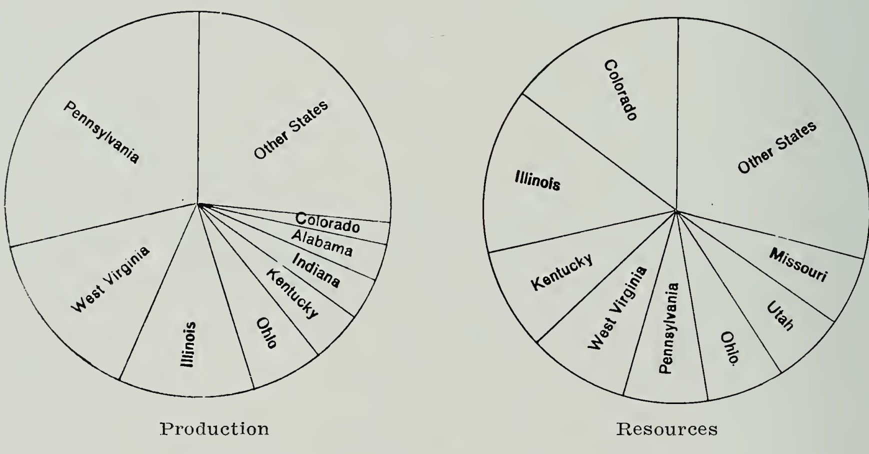

FIG. 1.—Diagram showing the relative available coal resources and production of the leading states, 1916. The source of the data on resources is Coal Resources of the World, XII International Geological Congress, 1913.

extent was the increase of nearly 2 per cent in the average daily output per man and an increase of 19 days, or more than 10 per cent, in the working time, which acted together to increase the average annual output per man from 778 to 876 tons.

The most notable feature of the year was the extension of the markets for Illinois coal. Normally the movement is to the west and north, supplying Wisconsin, Minnesota, and neighboring states, but in 1916 because of the unsatisfied demand for coal east of the Chicago district, coal from Illinois was shipped in considerable quantities to Michigan, to Ohio, and to Buffalo, and other New York points, where it was used as industrial and railroad fuel. In addition some Illinois coal was sold in Mississippi.

The ordinary demand for Illinois coal from the states northwest was augmented because of the failure of the usual eastern supply.

Although the number of men on strike in 1915 and in 1916 differed but little, 5,251 and 5,043 for these years, respectively, the strike periods were shorter in 1916, amounting to only 55,416 days as compared with 276,458 days in 1915, and the average number of days lost per man therefore decreased, from 53 in 1915 to 11 in 1916.

On April 1 of the "even" years, the biennial wage agreements expire, and there is usually a protracted period beginning in April, of labor suspension pending the settlement of new wage scales. The failure of the customary "even" year strikes to materialize in 1916 accounts therefore for the better strike record in that year than in 1915. And further, the relatively small amount of time lost because of labor troubles in the spring and summer did not cause an economic loss of production, as industries dependent on coal had realized the possibility of suspension of mining operations and had stocked quantities ample for their needs.

Illinois continued to hold its rank of third, a position it has maintained since 1909, when it yielded its second place to West Virginia. In total production of coal since 1833, when its mining first became a commercial industry, Illinois ranks second with a tonnage of 1,148,130,432. Pennsylvania holds highest rank, with 3,208,778,914 tons of bituminous coal mined since 1807 to its credit, and West Virginia follows Illinois with a record of 1,022,840,846 tons mined since 1863.

In total available resources, the rank of the states is different, Colorado leading, followed by Illinois, Kentucky, West Virginia, and Pennsylvania as shown graphically in figure 1.

The average price per short ton of Illinois coal at the mines from 1905 to 1916 is given in Table 6.

Table 6.—*Average price per short ton of Illinois coal at mines, 1905-1916*

1905	$1.06
1906	1.08
1907	1.07
1908	1.05
1909	1.05
1910	1.14
1911	1.11
1912	1.17
1913	1.14
1914	1.12
1915	1.09
1916	1.25

The production of coal by counties for the years 1905 to 1916 is given in Table 7. For the past three years Franklin County has held first rank,

TABLE 7.—*Production of coal in Illinois, by counties, in short tons, 1905-1916*

County	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916
Bond	126,231	132,325	138,990	60,129	89,861	139,398	119,250	232,571	223,786	123,730	27,659	86,805
Bureau	1,701,255	1,580,085	2.010,762	1,512,971	1,612,452	973,346	1,628,688	1,677,317	1,639,208	1.284,311	1,202,698	1,340,018
Calhoun	4,727	5,045	2,850	3,521	....	....	1,400	1,156	....	....	....	....
Christian	879,360	934,452	1,368.159	1,377,166	1,395,158	1,223,295	1,222,259	1,467,846	1,504,716	1,486,053	2,135,052	2,516,336
Clinton	579.281	515,796	1,302,391	1,078,848	970,709	950,243	921,225	1,040,479	1,049,575	1,090,787	1,315,648	1,307,712
Franklin	....	....	1,306,966	2,187,383	2,316,509	1,778,768	3,555,586	4,442.284	6,072,102	7,311,209	8.027,773	9,388,292
Fulton	1,529,249	1,579,224	2,113,643	2,012,415	2.388,617	1,721,527	2.133,029	2,453,424	2,388,775	2.052,170	1,849,906	2,109.950
Gallatin	82,682	92,731	78.055	59,667	64,713	70,091	63,008	64,244	46,105	81,735	77,380	66,933
Greene	4,435	2,206	2,310	9,506	7.318	9,082	6,207	7,841	5,009	6,665	5,764	2,963
Grundy	1,310,892	1,162,019	1,327,321	1,081,442	1,114,101	600,281	776,800	540,787	401,527	388,368	293,660	324,794
Hamilton	....	....	....	(c)	....	....	....	....	....	....	....	....
Hancock	3,300	4,498	2,034	1,406	1,085	640	230	....	....	1,678	1,285	2,656
Henry	146,995	149,188	149,721	141,624	137,060	124,243	90,722	58,613	43,383	47,010	46,219	44,502
Jackson	818,841	646,196	645,333	624,055	652.280	584,240	687,753	703,190	723,863	601,697	682,042	772,788
Jefferson	25,925	7,600	12,000	18,675	4.800	10,000	9,500	21,032	35,000	9,051	8,900	....
Jersey	....	1,397	1,162	1,496	1,000	....	....	....	....	....	....	....
Kankakee	700	39,499	26,704	30.994	25,000	....	....	....	....	....	....	....
Knox	58.972	51,654	40,996	41,040	21,973	28,295	30,136	22,293	18,280	14,150	11,985	9,897
La Salle	1,772,988	1.467,672	1,677,990	1,557,173	1,686,391	1,178,885	1,610,470	1,537,591	1,564.459	1,279,592	1,192,794	1,050,900
Livingston	284,984	273.831	303,497	265.666	246,031	162,898	89,423	65,774	63,877	64,461	63,341	110,709
Logan	445,546	435,559	477,115	372,980	395,888	409.244	334,860	466,528	351,666	352,181	311,346	465,159
McDonough	19,496	43,774	32,199	17,818	16.276	26,338	8,027	14,446	12,603	5,251	5,132	13,927
McLean	159,921	145,000	151,146	95,854	116,412	83,982	96,517	89.781	88,777	79,008	80,321	77,755
Macon	231,235	292,884	269,766	235,237	238,607	235,361	236,203	291,590	206,140	217,217	162,550	189,529
Macoupin	3,177,484	3,637,827	4.507,270	3,894,199	4,597,775	3,854,229	4,688,212	4,986,574	5,097,619	4,555,834	4,832,540	5,492,216
Madison	3,434,399	3.324.857	3,927,721	3,367,820	3.373,798	4,102,773	3,152,705	4,025,878	3,732,153	3,546,256	3,419,955	4,173,587
Marion	1,009,759	1,042,866	1,185,533	981,284	1,171,950	812.873	1,224,326	1,311,024	988,964	906,837	925,365	999,109
Marshall	499,672	418,904	482,796	393,281	295,812	267,447	423.984	449,660	426,490	383.331	408,566	438,983
Menard	415,266	429,971	389,918	355,309	303,948	332,557	190,477	177,578	120,174	76,603	78,893	159,336
Mercer	532,854	412,165	453,621	376,435	369,762	229,024	297,552	393,018	408,875	372,528	340,840	274,692
Montgomery	598,064	720,415	1,289,021	1,410,978	1,780,668	1,799,720	2,395,814	2,182,823	2,689,702	2,597,677	2,877,459	3,075,712
Morgan	4,565	9,100	5,513	3,244	1,200	1,300	1,268	1,000	1,222	[1]906	300	....
Moultrie	....	....	....	(d)	(f)	....	....	....	(d)	....	....	207,044
Peoria	897,946	914,863	1,103,312	921,929	914,961	810,595	1,037.362	1,225,574	1,163,073	1,055,323	1,193,351	1,307,900
Perry	1,298,572	1,509,716	1,784,469	1,576,891	1,423,135	1,367,771	1,272,292	1,444,114	2,013,128	2,236,480	2,383,658	2,474,573
Putnam	....	156,928	362,858	466.019	597,703	364,882	772,976	720,048	724,170	605,863	636,776	661,570
Randolph	440,991	634,270	824,761	751,605	799,893	1,025.557	777,746	798,163	763,472	956,582	892,948	965,089
Rock Island	68,383	62,321	52,938	50.781	46,228	66,207	65.983	66,817	35,672	36,022	24,747	33,580
St. Clair	3,329,914	4,904.811	4,511,879	3,696,017	3,471,630	5,788,567	3,931,479	4,734,840	4,383,459	3.246,322	2.908,129	4,172,697
Saline	675,701	980,864	2,247,842	2,552,137	3,283,939	2,459,650	3,820,410	4,417,874	4,189,003	3.746,656	4,166,249	4,153,516
Sangamon	4,324,263	4,543,849	5,160,042	5,015,608	5,616,357	4,449,634	5,137.835	5,714,742	5,875,853	5,679,595	5,075,823	5,128,970
Schuyler	2,880	3,090	7,553	15,269	4,573	2.427	6,138	4,573	1,855	2,781	5,864	8,115
Scott	13,423	12,437	17,639	3,427	2,056	2,400	464	460	600	1,000	1,000	1.000
Shelby	104,216	138,257	155,930	181,373	124,087	135,672	81,615	185,501	193,632	196,339	88,672	78,273

County	1905	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916
Stark	22,725	17,661	25,897	20,351	23,159	32,582	37,293	34,176	14,610	12,703	11,919	8,013
Tazewell	231,373	189,882	235,971	206,882	208,049	155,659	220,783	271,321	341,626	335,566	263,247	385,611
Vermilion	2,342,238	2,389,285	2,973,253	2,452,485	1,919,955	2,515,250	3,385,200	3,434,923	3,501,880	2,394,081	2,469,263	2,833,909
Warren	10,354	9,520	9,139	11,687	12,304	10,275	9,044	5,021	3,383	1,510	1,339	4,490
Washington	85,913	85,812	29,000	72,500	31,322	22,500	25,000	244,879	319,370	497,000	445,028	694,468
White	....	8,000	16,453	19,583	22,133	23,722	35,681	27,052	22,304	32,111	32,118	46,114
Will	137,957	154,955	183,985	162,239	162,307	124,652	178,397	130,806	149,926	136,758	141,416	80,885
Williamson	4,167,952	4,417,987	5,697,944	5,670,474	6,537,654	4,620,372	6,614,029	7,354,507	7,644,397	7,066,029	7,264,395	8,077,627
Woodford	[a]348,707	[a]717,566	[b]158,742	[e]174,031	194,410	125,823	164,001	185,499	[h]302,184	[h]315,840	[h]337,514	[i]192,045
Small mines	69,777	69,299	75,036	68,786	[g]111,981	85,969	109,759	157,994	71,097	98,340	100,747	103,587
Total	38,434,363	41,480,104	51,317,146	47,659,690	50,904,990	45,900,246	53,679,118	59,885,226	61,618,744	57,589,197	58,829,576	66,195,336
Total value	$40,577,592	$44,763,062	$54,687,382	$49,978,247	$53,522,014	$52,405,897	$59,519,478	$70,294,338	$70,313,605	$64,693,529	$64,622,471	$75,566,086

[a] Includes production of Franklin County.
[b] Includes production of Wabash County.
[c] Included with production of Hancock County.
[d] Included with production of Woodford County.
[e] Includes production of Edgar and Moultrie counties.
[f] Included with production of small mines.
[g] Includes production of Crawford and Moultrie counties.
[h] Includes production of Moultrie County.
[i] Includes production of Johnson County.

its output in 1916 having been 9,388,292 tons; Williamson County was a close second, with its 8,077,627 tons; Macoupin and Sangamon counties were almost tied for third place, with more than 5 million tons for each; and Madison, St. Clair, and Saline counties produced over 4 million tons each.

TABLE 8.—*Production of coal in Illinois by counties in short tons in 1916*

County	Loaded at mines for shipment	Sold to local trade and used by employees	Used at mines for steam and heat	Total quantity	Total value	Average value per ton	Average number of days active	Average number of employees
Bureau	1,258,151	43,613	38,254	1,340,018	$2,371,785	$1.77	230	2,667
Christian	2,348,261	123,618	44,454	2,516,336	2,835,806	1.13	187	2,999
Clinton	1,184,476	79,799	43,437	1,307,712	1,379,455	1.05	168	1,554
Franklin	9,095,314	58,813	234,165	9,388,292	12,590,987	1.34	198	8,726
Fulton	2,023,749	107,294	59,907	2,190,950	3,196,858	1.46	198	3,021
Gallatin	61,962	2,971	2,000	66,933	132,023	1.97	127	56
Greene	....	2,953	10	2,963	6,086	2.06	119	19
Grundy	289,914	17,062	17,818	324,794	658,417	2.00	205	727
Henry	....	42,157	2,345	44,502	85,367	1.92	242	88
Jackson	654,142	95,764	22,882	772,788	953,174	1.23	221	961
Knox	16	9,556	325	9,897	18,525	1.87	236	26
LaSalle	676,474	332,236	42,190	1,050,900	1,955,214	1.86	201	1,952
Livingston	27,174	80,215	3,320	110,709	173,472	1.57	243	174
Logan	354,280	87,728	23,151	465,159	675,814	1.45	202	641
McDonough	350	13,277	300	13,927	29,922	2.15	173	22
Macoupin	5,296,014	70,629	125,573	5,492,216	5,764,789	1.05	194	5,658
Madison	3,999,467	97,660	76,460	4,173,587	4,487,745	1.08	195	3,898
Marion	954,473	15,871	28,765	999,109	1,061,948	1.06	220	1,050
Menard	122,494	32,610	4,232	159,336	254,250	1.60	201	209
Mercer	241,307	19,814	13,571	274,692	441,611	1.61	232	365
Montgomery	3,013,211	22,471	40,030	3,075,712	3,588,721	1.17	185	3,271
Peoria	1,189,229	104,854	13,817	1,307,900	1,737,588	1.33	224	1,530
Perry	2,319,811	95,933	58,829	2,474,573	2,744,198	1.11	193	2,486
Randolph	915,117	31,018	18,954	965,089	1,088,811	1.13	186	1,183
Rock Island	....	32,629	951	33,580	61,769	1.85	158	78
St. Clair	3,765,653	273,396	133,648	4,172,697	4,561,588	1.09	169	4,934
Saline	4,023,759	46,883	82,874	4,153,516	4,965,770	1.20	192	4,030
Sangamon	4,740,471	263,498	125,001	5,128,970	6,341,221	1.24	179	6,269
Schuyler	....	8,115	....	8,115	17,230	2.12	189	27
Shelby	61,815	13,523	2,935	78,273	116,324	1.48	172	127
Stark	150	7,613	250	8,013	16,186	2.02	132	30
Tazewell	322,332	58,544	4,735	385,611	540,666	1.40	240	467
Vermilion	2,601,830	186,465	45,614	2,833,909	3,503,930	1.24	213	3,218
Washington	617,660	60,135	16,673	694,468	808,615	1.16	232	626
Williamson	7,800,824	67,870	208,933	8,077,627	9,621,744	1.19	198	8,694
Other counties[a] and small mines	1,526,462	479,570	86,431	2,092,463	3,670,345	....	....	3,755
State totals	61,486,342	3,086,157	1,622,837	66,195,336	$82,457,954	$1.25	198	75,538

[a]Bond, Hancock, Johnson, McLean, Macon, Marshall, Moultrie, Putnam, Scott, Warren, White, Will, and Woodford.

Figure 2 shows graphically not only the increases in tonnage and value of coal produced since 1905, but includes as well interesting comparative data on the number of mines and the tonnage mined by machine for the same period. The increasing distance between the curve for tonnage and that for value as 1916 is approached represents the advance in price per ton of coal at the mines, as given in Table 6.

Although the number of mines fluctuates from year to year, the tendency is clearly toward a decrease which is conspicuous in view of the marked increase in tonnage.

A number of factors probably combine to bring about this result.

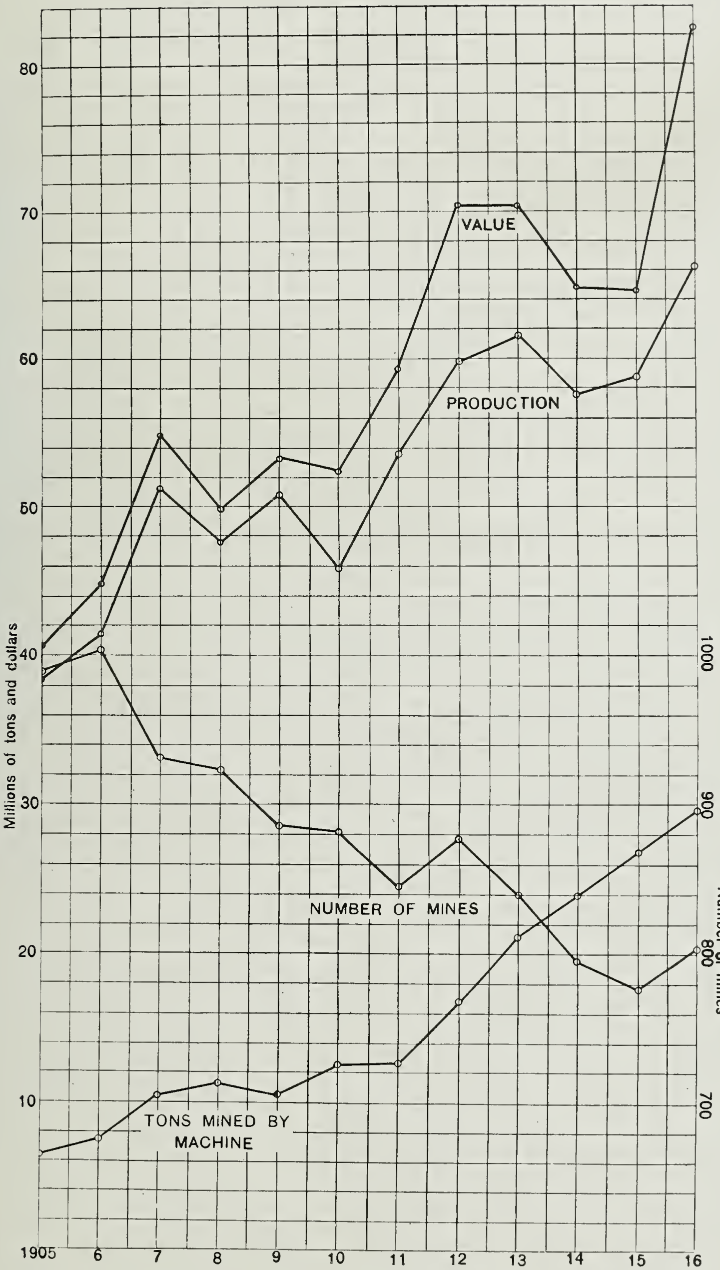

FIG. 2.—Diagram showing production and value of coal mined in Illinois, tonnage mined by machine, and total number of coal mines, 1916.

Among those which are to be classed as evidences of increasing efficiency are the extension of the use of machines for mining, the effects of which in increasing tonnage are illustrated by one of the curves of figure 2; and the substitution of a few large well-organized mines for numbers of smaller ones.

Another influence in driving many mines out of existence has been a steady decline in the margin of profit. The remarkable development of coal carrying and low ton-mile rates made for long railroad hauls has permitted the more cheaply produced eastern coals to move into Illinois and set prices that are too low to give much profit and therefore too low to permit efficient development of many of the mines. The ease of opening new mines in the State causes scores of them to spring up with every

TABLE 9.—*Statistics of the manufacture of coke in Illinois, 1905-1916*

Year	Establishments	Ovens		Coal used	Yield of coal in coke	Coke produced	Total value of coke at ovens	Value of coke at ovens per ton
		Built	Building					
				Short tons	*Per cent*	*Short tons*		
1905	5	275	....	16,821	61.3	10,307	$ 27,681	$2.69
1906	4	309	....	362,163	74.2	268,693	1,205,462	4.48
1907	5	309	280	514,983	72.3	372,697	1,737,464	4.66
1908	6	430	140	503,359	72.0	362,182	1,538,952	4.25
1909	5	468	40	1,682,122	75.9	1,276,956	5.361,510	4.20
1910	5	508	....	1,972,955	76.8	1,514,504	6,712,550	4.43
1911	4	506	48	2,087,870	77.1	1,610,212	6,390,251	3.97
1912	6	594	40	2,316,307	76.2	1,764,944	8,069,903	4.57
1913	4	568	58	2,481,198	74.9	1,859,553	8,593,581	4.62
1914	4	[a]586	[b]40	1,932,132	73.8	1,425,168	5,858,700	4.11
1915	4	[c]626	....	2,335,933	72.2	1,686,998	7,016,635	4.16
1916	4	[c]626	....	3.182,650	72.9	2,320,400	10,619,066	4.57

[a] Includes 253 Semet-Solvay, 315 Koppers, and 18 Wilputte ovens.
[b] Semet-Solvay ovens.
[c] Includes 293 Semet-Solvay, 315 Koppers, and 18 Wilputte ovens.

period of unusual prosperity, but with the slack spring and summer season, or the return of normal or subnormal prosperity, the effort of each of the many operators to keep his own mine going even at a slight loss results in excessive and really unfair competition. Proper organization or consolidation could of course partly remedy such difficulties, but to a certain extent they have been unavoidable, due to failure of the public to lay in winter supplies during slack seasons, partly due to the fallacious idea that Illinois coal cannot be stocked satisfactorily; and therefore labor rates have had to be high to cover the consequent period of summer idleness, even though the mines were reduced to a number more in keeping with the demand. Thus the decline in the margin of profit to which these conditions have led is a feature that is injurious to the interests of both producer and consumer, if carried too far, because except for the strongly capitalized companies, operators are not able with their profits to invest money in many improvements which would make for efficiency and eventually for greater profit.

COKE

Because of the 81 per cent increase in West Virginia's coke production in 1916, Illinois gave up its fourth rank to that State. The states of preceding rank, in order of importance, were Pensylvania, Alabama, Indiana, and West Virginia. The same four establishments as have contributed all the coke made in this State for the past four years continued to operate—the South Chicago, Waukegan, and two Joliet plants. Statistics of the manufacture of coke in Illinois from 1905 to 1916 make up Table 9.

PIG IRON

The period of intense activity in the country's iron industry which began in the last half of 1915, stimulated by the war in Europe, and continued throughout 1916, is reflected in Illinois statistics by the record-breaking output of 3,857,391 tons of pig iron valued at $67,764,309. The average percentage of increase in output and value for the United States, amounting to 29 per cent and 65 per cent, respectively, is even exceeded by Illinois' gains of 57 per cent and 98 per cent for quantity and value of pig iron produced in 1916, as compared with 1915.

Table 10 shows the annual production of pig iron for the past ten years. The State maintained its usual rank of third among the states in 1916, Pennsylvania and Ohio alone preceding it.

TABLE 10.—*Production in long tons and value of pig iron in Illinois, 1907-1916*

Year	Quantity	Value	Average price per ton	Year	Quantity	Value	Average price per ton
1907.......	2,457,768	$52,229,000	$21.25	1912.......	2,806,378	$42,828,816	$15.26
1908.......	1,691,944	30,135,000	17.81	1913.......	2,892,263	45,796,966	15.83
1909.......	2,467,156	44,211,000	17.92	1914.......	1,793,714	24,382,458	13.59
1910.......	2,675,646	42,917,362	15.91	1915.......	2,455,894	34,207,901	13.93
1911.......	2,036,081	31,152,927	15.30	1916.......	3,857,391	67,764,309	17.57

The ore from which the pig iron was manufactured came as usual from Lake Superior ports; Michigan, Wisconsin, and Minnesota each contributing a part of the 7,740,877 tons received at South Chicago, the Illinois port on Lake Michigan. Of the 24 blast furnaces operating in 1916, twenty are at South Chicago and the remaining four at Joliet.

PETROLEUM

Illinois has been one of the important contributors to the petroleum supply of the United States since 1906, its output in 1908 reaching a max-

mum of nearly 34,000,000 barrels. Since that year, its production has declined at an average rate of 6 per cent a year, amounting in 1916 to about 53 per cent of the maximum.

That the output of petroleum in Illinois in 1916 was 17,714,235 barrels, a loss of 1,327,460 barrels, or 7 per cent as compared with 1915, is to be accounted for by the failure of the drilling campaign in 1916 to discover enough new production to offset the deficit resulting from the normal decline of the old wells.

Market conditions were never better than in 1916, the average price per barrel for Illinois oil in 1916 being $1.65, compared with 98 cents the year before. As a consequence of this gain of 68 per cent in average price, the market value of the entire output of Illinois oil in 1916 was $29,237,168, a sum greater than the value of the production in any other year, the year of maximum yield, 1908, included.

The incentive provided by the advancing market for Illinois oil in the early months of 1916 and again near the end of the year resulted in the completion of 1,461 new wells, compared with only 757 in 1915. Of these, 1,107 or 76 per cent, were credited with an average initial production of 22 barrels of oil, 36 produced gas only, and 318, an average of 2 in every 9 drilled, were barren. The ratio of dry holes to total completions in 1916 is an improvement over that of 5 to 19 maintained in 1915.

In the "shallow-sand" district of Cumberland, Coles, Clark, Edgar, and Jasper counties, a total of 307 wells, including 258 oil wells, 7 gas wells, and 42 dry holes, was completed. The average initial capacity of the new oil wells was 16 barrels, a loss of 3 barrels compared with the average in 1915. Considerable effort was directed to the quest for extension of the "shallow-sand" district both to the north into Ashmore Township, Coles County, and to the east into Dolson and Martinsville townships, Clark County; but advance tests in these directions were failures.

The "deep-sand" fields of Crawford and Lawrence counties were the centers of the greatest activity in drilling in Illinois in 1916, as indicated by the fact that 55 per cent of the wells completed were in these counties. Of 815 wells completed in these counties 603, or 74 per cent, were credited with an average initial output of 26 barrels of oil each; 26 were gas wells; and 186, an average of about 2 in every 9, were failures. Most of the drilling was restricted by necessity to proved areas, as efforts to find extensions and new territory of worth were disappointing.

In the Allendale pool, Wabash Township, Wabash County, 29 wells were completed in 1916. Seventeen were oil wells credited with a combined yield of 2,325 barels, or an average of 137 barrels each. Wildcat tests seeking extensions of this "spotted" pool toward the south and west were unsuccessful.

The Sandoval pool, in Sandoval Township, Marion County, supported an active development in 1916 that resulted in the completion of 18 oil wells, with an average initial capacity of 11.5 barrels each, and 8 dry holes.

Drilling activity in Clinton County in 1916 resulted in the completion of 11 oil wells and 23 dry holes. The completion in January, as an oil well, of a test on the Hoffsomier farm, in sec. 12, Breese Township, about 3 miles west of the Carlyle pool, resulted in the drilling or additional tests and the partial development of a small but "spotted" pool in this locality.

The Carlinville pool, in Brushy Mound Township, passed a featureless year, no new wells having been completed in 1916. Further drilling on the Staunton dome, in Dorchester Township, added 3 gas wells to the gas field opened in 1915 on this structure. Arrangements were completed for the utilization of the gas from this field, and a pipe line was laid to

Table 11.—*Marketed production of petroleum in Illinois, 1889-1916*

Year	Marketed production	Percentage of total production	Increase or decrease		Value	Yearly average price per barrel
			Barrels	Per cent		
1889.....	1,460	.....	....	....	$ 4,906	$3.360
1890.....	900	.....	— 560	— 38.36	3,000	3.333
1891.....	675	.....	— 225	— 25.00	2,363	3.500
1892.....	521	.....	— 154	— 22.81	1,823	3.500
1893.....	400	.....	— 121	— 23.22	1,400	3.500
1894.....	300	.....	— 100	— 25.00	1,800	6.000
1895.....	200	.....	— 100	— 33.33	1,200	6.000
1896.....	250	.....	+ 50	+ 25.00	1,250	5.000
1897.....	500	.....	+ 250	+ 100.00	2,000	4.000
1898.....	360	.....	— 140	— 28.00	1,800	5.000
1899.....	360	.....	....	....	1,800	5.000
1900.....	200	.....	— 160	— 44.44	1.000	5.000
1901.....	250	.....	+ 50	+ 25.00	1,250	5.000
1902.....	200	.....	— 50	— 20.00	1,000	5 000
1903.....	....	.....	— 200	— 100.00	....	......
1904.....	....	.....	....	....	....	......
1905.....	181,084	0.13	+ 181,084	....	116,561	.644
1906.....	4,397,050	3.47	+ 4,215,966	+2,328.18	3,274,818	.745
1907.....	24,281,973	14.62	+19,884,923	+ 452.23	16,432,947	.677
1908.....	33,686,238	18.87	+ 9,404,265	+ 38.73	22,649,561	.672
1909.....	30,898,339	16.87	— 2,787,899	— 8.28	19,788,864	.640
1910.....	33,143,362	15.82	+ 2,244,923	+ 7.27	19,669.383	.593
1911.....	31,317,038	14.21	— 1,826,224	— 5.51	19.734,339	.639
1912.....	28,601,308	12.83	— 2,715,730	— 8.67	24,332,605	.851
1913.....	23,893,899	9.62	— 4,707,409	— 16.45	30,971.910	1.296
1914.....	21,919,749	8.25	— 1,974,150	— 8.26	25,426,179	1.160
1915.....	19,041,695	6.77	— 2,878,054	— 13.13	18,655,850	.980
1916.....	17,714,235	5.89	— 1,327,460	— 6.97	29.237,168	1.650
	269,082,546	6,869	....	....	230,316,777	.856

Staunton, Edwardsville, Marysville, Collinsville, and Belleville.

The proved area of the Hoing and Hamm pools in the Colmar district was essentially drilled up by the completion in 1916 of 211 wells, 186 of which produced an average of 10 barrels of oil each, the first 24 hours after completion. In efforts to extend this field 25 dry holes were drilled in McDonough County alone.

Persistent efforts to extend the Colmar field westward into Hancock County were rewarded in 1916 by the discovery and partial development of a small pool of oil on the Aleshire farm, in secs. 24 and 13, St. Marys Township.

NATURAL GAS

It is estimated that 3,533,701,000 cubic feet of natural gas was produced and consumed in Illinois in 1916, this production representing an increase of 31 per cent over the output in 1915.

The gain is accounted for in part by the increased utilization of southeastern oil-field gas for the manufacture of gasoline, and in part by the new production from the Staunton gas field in which gas was discovered in 1915, though not distributed to consumers until late in 1916.

The market value of the gas in 1916 was $396,357, an increase of only 13 per cent over the market value of the output in 1915, in spite of the large increase in quantity. Explanation of the decrease in value—from an average of 13.02 cents per thousand in 1915 to 11.22 cents in 1916—lies to some extent in a general reduction in price for both domestic and industrial consumers, but chiefly in the greater relative consumption of gas for industrial uses in 1916 than in other recent years.

The following list contains the names of cities and towns in Illinois which were either wholly or in part supplied with natural gas in the year 1916:

Annapolis	Duncanville	Lawrenceville	Palestine
Belleville	Eaton	Marshall	Pinkstaff
Birds	Edwardsville	Martinsville	Robinson
Bridgeport	Flat Rock	New Hebron	Staunton
Carlinville	Greenville	Oblong	Stoy
Casey	Heyworth	Olney	Sumner
Collinsville	Hutsonville		

Of this list Heyworth is the only one using natural gas from drift wells, all the others obtaining their supplies from Mississippian and Pennsylvanian sands. Belleville, Collinsville, Edwardsville, and Staunton are supplied by the Staunton gas field; a small pool in Bond County affords gas for Greenville; and the other towns all use gas from the southeastern Illinois oil fields.

TABLE 12.—*Record of natural gas industry in Illinois, 1906-1916*

Year	Gas produced		Gas consumed			Wells		
	Number of producers	Value	Number of consumers		Value	Drilled		Productive Dec. 31
			Domestic	Industrial		Gas	Dry	
1906	66	$87,211	1,429	2	$87,211	....	....	200
1907	128	143,577	2,126	61	143,577	94	41	283
1908	185	446,077	[a]7,377	[a]204	[a]446,077	121	42	400
1909	194	644,401	[a]8,458	[a]518	[a]644,401	56	11	423
1910	207	613,642	[a]10,109	[a]261	[a]613,642	64	31	458
1911	225	687,726	[a]10,078	[a]293	[a]687,726	69	78	458
1912	223	616,467	[a]10,691	[a]212	[a]616,467	56	147	453
1913	231	574,015	[a]10,423	[a]279	[a]574,015	60	119	455
1914	235	437,275	[a]8,952	[a]153	[a]437,275	38	114	417
1915	221	350,371	[a]8,610	[a]134	[a]350,371	28	67	378
1916	218	396,357	[a]14,485	[a]121	[a]396,357	36	126	343

[a]Includes number of consumers and value of gas consumed in Vincennes, Indiana

NATURAL-GAS GASOLINE

As the natural-gas gasoline industry is one of the most effective movements in the direction of true conservation of natural gas that has ever been undertaken in this country, it is gratifying to see that the quantity of gas treated in this State is increasing rapidly each year. In spite of the 118 per cent increase in marketed production in 1916 over that for 1915, Illinois produced only 2.2 per cent of the country's output, and consequently ranks relatively low—sixth among the states.

Three of the 32 plants were absorption plants installed by one company in Lawrence County during the year. An average of 1.69 gallons of gasoline was obtained for each thousand cubic feet treated in 1916, a net decrease of .60 gallons per thousand cubic feet from the average in 1915. This decrease does not indicate a diminution in the content of gasoline vapors of Illinois gas or loss of efficiency in the operating gasoline plants; rather it represents an encouraging increase in the use of lean gas for manufacture of gasoline. The statistical effect of the use of lean gas is of course to increase the volume treated, and to lower the average recovery of gasoline per unit volume of gas, but to give a net increase in total production and at the same time to better conserve the gas.

TABLE 13.—*Production of gasoline from natural gas in Illinois, 1913-1916*

	1913	1914	1915	1916
Number of plants	12	14	16	32
Quantity ....gal.	581,171	1,164,178	1,035,204	2,260,288
Value	$67,106	$100,331	$80,049	$262,664
Price per gallon....cents	11.54	8.62	7.73	11.58
Gas used....M cu. ft.	160,304	462,321	552,054	1,338,594
Average yield per M cu. ft. gal.	3.63	2.52	2.29	1.69

ASPHALT

No deposits of natural asphaltic material are known in Illinois. Certain grades of crude petroleum produced in this State are, however, utilized as sources of manufactured asphalt. In 1916 four refineries utilizing Illinois oil produced and sold 155,406 short tons of manufactured asphalt, valued at the plants at $1,285,470, the greater part of which was marketed for use in oiling roads and as a flux. One additional refinery located in this State manufactured asphalt from petroleum obtained from Kansas and Oklahoma.

CLAY-WORKING INDUSTRIES

Clay

In 1915 Illinois had dropped from fifth to sixth rank in quantity of clay mined, although in the value of production it had maintained its sixth rank of the previous year. In 1916, advances were so large (see Table 14) as to permit the State to regain its fifth rank for quantity and

Table 14.—*Production in short tons, and value of clay mined and marketed in Illinois, 1902-1916*

Year	Fire clay		Other clays		Total	
	Quantity	Value	Quantity	Value	Quantity	Value
1902	(a)	(a)	(a)	(a)	52,152	$ 38,463
1903	36,239	$ 38,027	34,799	$35,815	71,038	73,842
1904	55,922	43,863	33,043	27,223	88,965	71,086
1905	50,922	53,726	76,806	66,684	127,728	120,410
1906	44,989	50,793	94,715	81,479	139,704	131,272
1907	66,525	55,545	57,250	50,158	123,775	105,703
1908	39,075	47,039	78,007	67,443	117,082	114,482
1909	45,806	73,884	98,254	76,984	144,060	150,868
1910	82,878	111,078	105,925	79,818	188,803	190,896
1911	71,479	91,623	111,357	92,203	182,836	183,826
1912	92,963	110,204	83,595	82,459	176,558	192,663
1913	106,216	125,477	88,721	78,560	194,937	204,037
1914	125,071	138,876	36,013	29,478	161,084	168,354
1915	93,888	120,008	70,016	49,312	163,904	169,320
1916	131,658	327,666	66,043	50,774	197,701	378,440

[a] Concealed in "Total."

to achieve similar rank for value of output. The increase of 20 per cent in quantity, and 112 per cent in value is not typical of the percentage of increase for all or even many of the clay-producing counties. In fact, of eight counties reporting production, three suffered actual decreases,

and three had only minor increases. La Salle County enjoyed 33 per cent and 43 per cent increases in quantity and value, respectively, but Union County made phenomenal advances of 157 per cent and 84 per cent for tonnage and value of clay mined.

The opening up of the exceptionally fine deposits of refractory clay described in the following report of this volume is responsible for the Union County increases, and indeed in large measure for the State's advance as well.

La Salle County yielded its first position in value of clay produced to Union County, but maintained its leadership for tonnage, McDonough following it and preceding Union County. The La Salle County clay comes from a highly refractory bed in the Pottsville formation; McDonough, Greene, and Scott counties mine the Cheltenham fire clay, in the Pottsville formation. Stoneware clay to the value of $24,970 was reported from Greene and McDonough counties, and a very small amount of medicinal clay from Ogle County.

Clay Products

In total value of clay products, Illinois continued to rank fourth, a position it has held since 1907. Ohio, Pennsylvania, and New Jersey are the states of higher rank, named in order of importance. Considering only brick and tile products, Illinois now ranks third, having displaced New Jersey from that position. In both branches of the industry, there was increase over 1915, amounting to about 19 per cent for each.

Almost every variety of clay product was manufactured. In value and quantity of common brick, the State ranked first, as it has for a number of years, and in value of architectural terra cotta it rose from second place in 1915 to first in 1916. In quantity and value of vitrified brick it continued to stand second; in the value of front brick and draintile, fourth; and in the value of sewerpipe and fireproofing, fifth.

Of the 102 counties in Illinois, 70 reported production of one or more varieties of clay products. As usual, Cook County led with a total value of $236,805 for pottery, including red earthenware, stoneware, and sanitary ware, and of $6,395,608 for brick and tile products, including common brick, architectural terra cotta, fireproofing, and floor tile. These values constitute 36 per cent of the State value. La Salle, Vermilion, and Knox counties rank second, third, and fourth, respectively, the value of production for each being about 6 per cent of the State total.

Fire brick, fireproofing, draintile, and front brick are the principal products of La Salle County; common brick, vitrified paving brick and front brick for Vermilion County; and vitrified brick for Knox County. It is interesting to note that whereas last year no county except Cook reached the half-million-dollar mark, in 1916 three counties besides Cook

TABLE 15.—*Clay products in Illinois, 1907-1916*

Product	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916
Brick;										
Common—										
Quantity	1,494,807.000	1,119,224,000	1,257,025,000	1,196,526,000	1,074,486,000	1,210,499,000	1,155,480,000	941,343,000	1,066.057,000	1,182,473,000
Value	$6,499,777	$4,834,652	$5,927,054	$6,896,836	$6,126,911	$6,437,331	$6,445,821	$4,898,698	$6,870,990	$6,738,152
Average per M	$4.35	$4.32	$4.72	$5.76	$5.70	$5.32	$5.58	$5.20	$6.45	$5.70
Vitrified—										
Quantity	126,927,000	138,362,000	140,105,000	115,903,000	124,623,000	136,708,000	133,938,000	157,176,000	142,689,000	175.989,000
Value	$1,405,821	$1,622,496	$1,562,373	$1,415,355	$1,627,683	$1,839,721	$1,883,199	$2,086,344	$1,796,350	$2,465,179
Average per M	$11.08	$11.73	$11.15	$12.21	$13.06	$13.46	$14.06	$13.27	$12,59	$14.02
Front—										
Quantity	20.828.000	22,851,000	32,416,000	22,138,000	19,786,000	21,894,000	29,566,000	46,995,000	58,107,000	74,652,000
Value	$266,270	$301,515	$385,170	$274,699	$240,135	$268,433	$363,010	$506,984	$635,686	$810,440
Average per M	$12.78	$13.19	$11.88	$12.41	$12.14	$12.26	$12.28	$10.79	$10.94	$10.92
Fancy or ornamental, ...value	(a)	(a)	$12,223	$10,875	$10,281	$8,785	$2,295	(a)	(a)	(a)
Enameled ......value	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Fire ......value	$241,008	$250,444	$682,793	$368,730	$286,039	$319,619	$351,324	$274,106	$320,740	$523,442
Stove lining ......value	(a)	(a)	....	....	....	....	....	(a)	(a)	(a)
Draintile ......value	$1,031,192	$1,421,878	$1,613,593	$1,613,698	$1.372,049	$1,189,910	$1,225,190	$1.041,927	$991,709	$1,200,465
Sewer pipe ......value	$662,487	$514,386	$394,461	$538,633	$507,694	$500,844	$787,896	$743,986	$569,536	$768,410
Architectural terra cotta ......value	(a)	(a)	$1,898,865	$1,680,438	$1,879,275	$2,485,012	$1,908,399	$1,652,945	$1,289,848	$1.980,781
Fireproofing ......value	$429,535	$264,986	$439,796	$552,905	$552,994	$507,222	$592,337	$567,266	$492,138	$769,929
Tile, not drain ......value	(a)	$124,425	$335,020	(a)	(a)	(a)	$82,168	(a)	(a)	(a)
Pottery:										
Red earthenware.value	$37,045	$24,821	$31,771	$25,658	$41,875	$35,827	$46,175	$37,452	$40,810	$46,843
Stoneware and yellow and Rockingham ware ......value	$898,267	$733,373	$702,411	$708,958	$832,813	$675,244	$624,194	$483,407	$572,958	$548,633
White ware including C. C. ware, white granite. semiporcelain ware and semivitreous porcelain ware..value	(a)	(a)	(a)	....	(a)	(a)	(a)	(a)	(a)	(a)
Sanitary ware ....value	....	....	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)
Porcelain electrical supplies ......value	(a)	....	....	....	(a)	(a)	(a)	(a)	(a)	(a)
Miscellaneous ......value	$1,749,087	$1,466,138	$358,923	$1,089,376	$855,262	$943,042	$883,866	$1,025,838	$1,211,173	$1,781,077
Total value	$13,220,489	$11,559,114	$14,344.453	$15,176,161	$14,333,011	$15,210,990	$15,195,874	$13.318,953	$14,791,938	$17,633,351
Number of active firms reporting	417	400	379	346	330	301	281	263	254	213
Rank of State	4	4	4	4	4	4	4	4	4	4

[a] Included in "Miscellaneous."

surpassed the million-dollar mark, and four more were credited with almost that value of clay products.

Common brick again surpassed all other clay products, its value comprising 38 per cent of the State total. Cook County led with 69 per cent of the total value for common brick, the same per cent as for the preceding year. Figure 3 shows graphically the relative production of the leading counties.

Of second importance was vitrified brick, chiefly paving blocks, making up 14 per cent of the total for clay products, most of which was from

TABLE 16.—*Production and value of brick and draintile in Illinois, by counties, 1916*

County	Common Brick		Draintile	Other Brick and Tile Products	Total Value
	Thousands	Value	Value	Value	
Adams	4,357	$ 30,505	....	$ 1,570	$ 32,075
Bureau	2,392	15,422	$ 54,061	119,263	188,746
Christian	980	7,138	10,724	....	17,862
Cook	833,164	4,623,480	....	1,772,128	6,395,608
Edwards	1,976	12,498	2,500	232,170	247,168
Fulton	7,925	42,875	8,000	....	50,875
Gallatin	263	1,950	2,500	500	4,950
Grundy	29	292	61,520	10,816	72,628
Hancock	352	3,073	11,801	22,667	37,541
Henry	296	2,170	2,480	2,800	7,450
Iroquois	105	871	42,560	....	43,431
Kane	1,239	8,055	41,262	2,951	52,268
La Salle	2,080	14,658	171,213	935,111	1,120,982
Lee	200	1,700	25,200	....	26,900
Livingston	12,330	91,468	46,207	759,952	897,627
Logan	420	2,900	2,587	....	5,487
McDonough	1,425	10,100	86,350	315,959	412,409
McLean	2,354	15,080	1,800	4,635	21,515
Madison	11,219	80,635	20,300	324,694	425,629
Montgomery	137	1,100	4,040	55,542	60,682
Morgan	1,289	10,585	10,252	....	20,837
St. Clair	19,535	151,120	....	62,497	213,617
Sangamon	5,307	37,982	39,390	185,618	262,990
Tazewell	17,539	87,695	12,290	51,753	151,738
Vermilion	66,895	435,869	2,000	661,657	1,099,526
White	1,125	7,850	13,650	350	21,850
Other counties[a]	187,440	1,041,081	527,778	3,046,595	4,615,454
State Totals	1,182,473	$6,738,152	$1,200,465	$8,569,228	$16,507,845

[a] Including: Boone, Cass, Champaign, Clinton, DeWitt, Douglas, Dupage, Edgar, Effingham, Fayette, Greene, Hamilton, Jackson, Jersey, Kankakee, Knox, Lake, Lawrence, McHenry, Macon, Macoupin, Marion, Mason, Massac, Menard, Mercer, Moultrie, Ogle, Peoria, Pike, Pulaski, Randolph, Rock Island, Saline, Schuyler, Scott, Shelby, Stark, Stephenson, Warren, Washington, Will, Williamson, and Woodford.

Knox County. Architectural terra cotta ranked third with an 11 per cent value, Cook ranking first among the counties in its production with four-fifths of the total production, and McHenry second with almost one-fifth. Fourth in monetary importance was draintile, its value comprising 7 per cent of the total for clay products. La Salle County led, producing 17 per cent of the State's draintile; Kankakee and Greene counties were second and third, with 12 and 11 per cent, respectively; McDonough, Mer-led with 25 per cent of the pottery value, followed by McDonough, Knox, cer, Grundy, and Bureau counties followed with from 5 to 10 per cent, and 39 other counties produced less than 5 per cent.

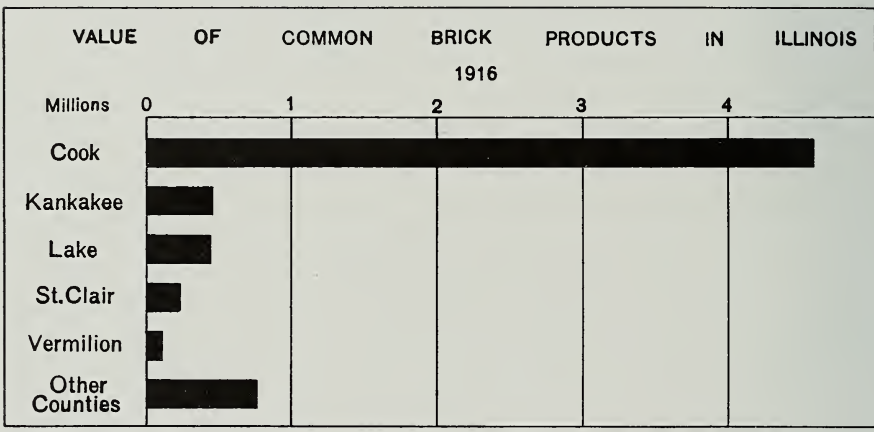

FIG. 3.—Diagram showing the relative production of common brick for the leading counties, 1916.

Fifth in rank according to value was pottery, aggregating 6.4 per cent of the State value for all clay products. In this class, Warren County and Cook counties, each with a little more than 20 per cent of the total pottery value to its credit.

STONE

Both sandstone and limestone are produced in Illinois, but the latter is by far the more important product, valued as it is at almost 100 times the former. That a part of the stone reported as sandstone is really in one instance a soft granular limestone, and in another flint or chert makes the relative production of true sandstone even smaller than is apparent from the statistics. Table 17 gives the value of the production of both varieties of stone for the years 1903 to 1916.

In value, sandstone production decreased 7 per cent, limestone production increased 16 per cent, and the combined stone production of the

TABLE 17.—*Values of production of sandstone and limestone in Illinois, 1903-1916*

Year	Sandstone	Limestone	Year	Sandstone	Limestone
1903..........	$26,293	$3,206,271	1910..........	$ 5,710	$3,847,715
1904..........	47,377	3,151,890	1911..........	30,953	3,436,977
1905..........	29,115	3,511,890	1912..........	32,720	3,808,784
1906..........	19,125	2,942,331	1913..........	28,781	4,112,172
1907..........	14,996	3,774,346	1914..........	72,738	2,861,340
1908..........	12,218	3,122,552	1915..........	43,307	2,864,103
1909..........	26,891	4,234,927	1916..........	40,343	3,362,751

State increased 17 per cent as compared with 1915. In view of the decided decline that affected the limestone industry during 1914 and 1915, the increases noted above are very encouraging.

As usual Cook County led among the 29 counties, reporting an output valued at $1,991,830, which constituted 59 per cent of the State total.

The four counties of following rank were Will, St. Clair, Kankakee, and Madison, the first two of which produced 7 per cent and 6 per cent, respectively, and the second two each about 3 per cent. Vermilion County, which in the previous year had ranked third, disappeared from among the ten leading counties, its decline doubtless being partly a result of the closing of the Universal Portland Cement Company's South Chicago plant, which had formerly taken large quantities of stone from the Fairmount quarries.

The accompanying map (fig. 4) shows in graphic form the distribution of high- and low-magnesian limestones in the State, as indicated by the hundred odd analyses published in Survey reports or found in the Survey's files. As the map shows where the rocks of the different systems outcrop, distribution of the various varieties of limestones in relation to system boundaries gives the basis for a number of interesting generalizations. For example, the limestones of the Silurian system of rocks are apparently consistently high-magnesian, those of the Mississippian and Devonian are almost as consistently low-magnesian, and those of the Ordovician, although in most instances high-magnesian, are locally so low in magnesium content as to rival the Mississippian limestones. Conversely, Silurian and most Ordovician limestones are low-calcium, for the percentage of minerals other than calcium and magnesium carbonates is in general so low as to have a negligible effect in the classification of the rocks as high- or low-calcium or magnesian.

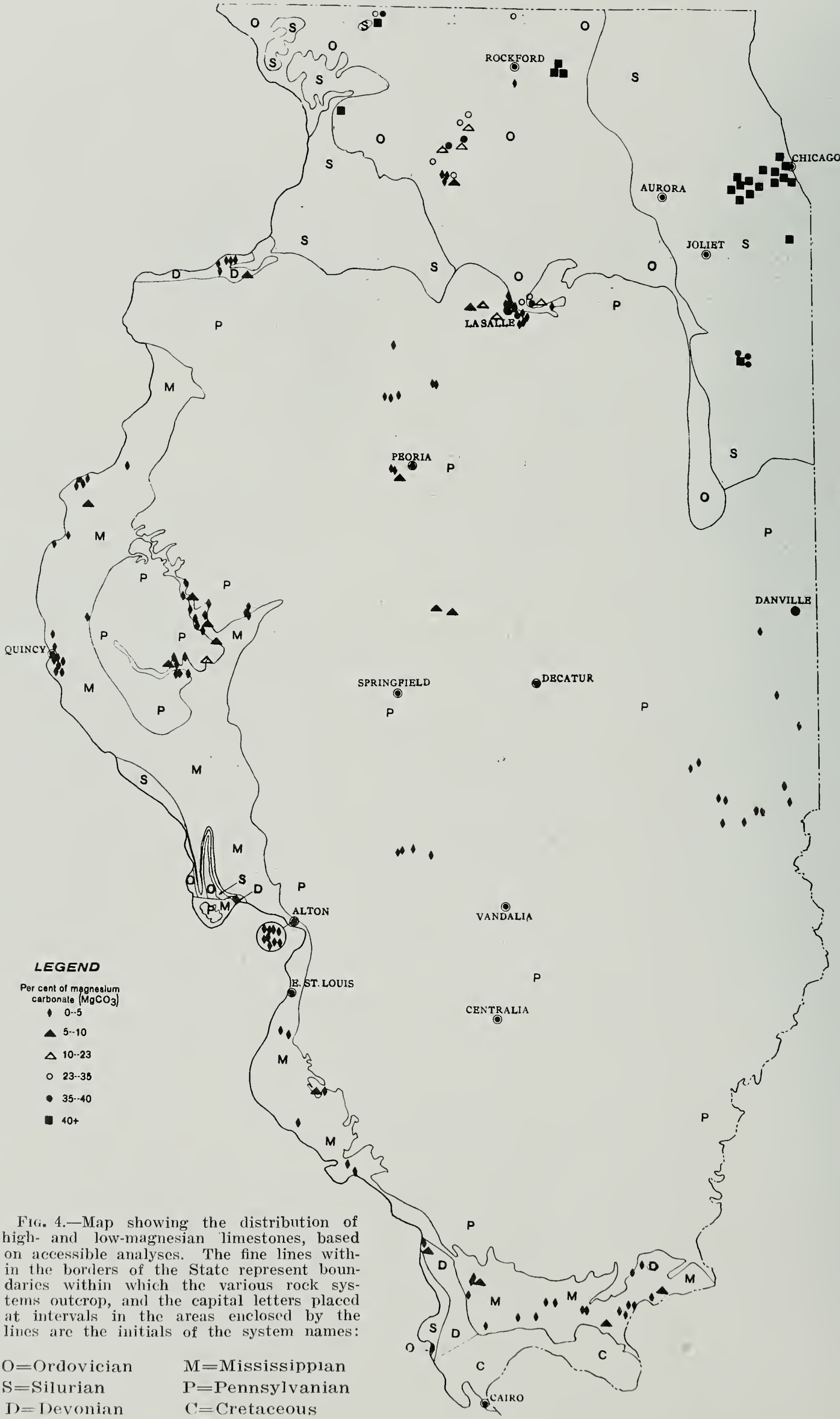

FIG. 4.—Map showing the distribution of high- and low-magnesian limestones, based on accessible analyses. The fine lines within the borders of the State represent boundaries within which the various rock systems outcrop, and the capital letters placed at intervals in the areas enclosed by the lines are the initials of the system names:

O=Ordovician M=Mississippian
S=Silurian P=Pennsylvanian
D=Devonian C=Cretaceous

Similarly Mississippian and Devonian rocks classed as low-magnesian may be safely deduced to be high-calcium, for in the majority of instances these limestones are of high purity; the reservation must be made, however, that in certain localities and formations, the content of silica in the form of chert may be so great as to keep the rocks out of the high-calcium group even though they may have an exceptionally low magnesium content.

The distribution on the map of symbols representing analyses is a fair index of the general distribution of limestone outcrops and thus indirectly of quarries. The lack of many analyses and the absence of many quarries in the broad central area underlain by Pennsylvanian rocks, is due partly to the fact that central Illinois is so heavily covered with drift that limestones that might otherwise be quarried are not accessible because of the heavy overburden; and partly to the fact that the Pennsylvanian system has relatively few limestones associated with the shales, sandstones, and coals which are its predominant constituents.

The value of the stone used for concrete comprised a little over 36 per cent of the total State value; the value of stone for road making, 24 per cent; and the value for flux and railroad ballast, about 12 per cent. These percentages are practically identical with those for 1915. Other uses of the limestone were for fertilizer, rubble, riprap, building stone, glass factories, curbing, flagging, carbonic acid plants, and sugar factories.

The weights of crushed stone per cubic yard, all limestone with one exception, compiled by the U. S. Geological Survey from reports by producers is given below. Although the list is by no means comprehensive, it will probably be of interest to those interested in construction work and the testing of materials.

Alexander County, Tamms (novaculite)	2,160
Adams County, Quincy	2,500
Boone County, Belvidere	2,500
Clark County, Casey	2,750
Cook County:	
Chicago	2,500
La Grange	2,500
Lyons	2,500
Thornton	2,500
Crawford County, West York	2,700
Dupage County, Elmhurst	2,500
Jersey County, Grafton	2,330
Jo Daviess County, Stockton	2,500
Kane County, Batavia	2,500
La Salle County, Ottawa	2,500
Lee County, Dixon	2,500
Ogle County, Polo	2,800

Randolph County:	
Menard	2,500
Red Bud	2,700
St. Clair County:	
Falling Springs	2,430
Krause (Millstadt)	2,400
Stephenson County, Freeport	2,700 2,500
Union County, Anna	2,300
Whiteside County, Sterling	2,800
Will County, Joliet	2,500
Winnebago County:	
Rockford	2,500
Shirland	2,600

LIME

In 1916 Illinois ranked fifteenth in quantity and sixteenth in value of lime produced. As compared with 1916 the quantity decreased almost 10 per cent; but the increase in average price per ton from $3.98 to $4.61 gave an increase in total value of more than 4.5 per cent. Statistics for the lime industry from 1904 to 1916 are given in Table 18.

Table 18.—*Lime burned in Illinois, 1904-1916*

Year	Number of plants	Quantity	Value	Average price per ton
		Short tons		
1904	..	108,881	$461,068	$4.23
1905	..	98,907	421,589	4.26
1906	..	121,546	534,118	4.39
1907	22	124,784	559,305	4.48
1908	18	92,549	393,951	4.26
1909	17	104,260	454,682	4.36
1910	14	113,239	503,581	4.45
1911	16	92,169	423,762	4.60
1912	15	98,450	394,892	4.01
1913	16	95,977	433,331	4.51
1914	16	87,603	362,727	4.14
1915	14	88,604	352,954	3.98
1916	12	80,012	369,038	4.61

Of the total production, 54 per cent is used for building purpose, 21 per cent for chemical works, 9 per cent for paper mills, and the remaining 16 per cent is taken up for sugar factories, tanneries, fertilizer, and miscellaneous purposes.

Named in order of rank, lime was burned in the following counties: Adams, Cook, Madison, Rock Island, Winnebago, Kankakee, and Will counties. Cook and Adams counties together produced 84 per cent of the State's total. High-calcium lime comes from Adams, Madison, and Will counties and makes up about 60 per cent of the total; high-magne-

sian lime is burned in the other counties and constitutes about 40 per cent of the total production. Both high-magnesian and high-calcium limes are used in the building trades, but only the high-calcium goes to chemical works, paper mills, sugar factories, and tanneries.

As brought out on a preceding page the limestones north of the coal basin are almost entirely of Ordovician and Silurian age, and in general are high-magnesian (see figure 4). The limestones outcropping along the Mississippi River south from Henderson County and bordering the west side of the coal basin are largely high-calcium. They are principally of Mississippian age except for an area of Devonian strata in Jackson, Union, and Alexander counties, and small Ordovician areas in Calhoun, Monroe, and Alexander counties.

A few analyses typical of the Ordovician and Silurian deposits of northern Illinois, and of the Mississippian, Devonian, and Ordovician of western Illinois are here given as typical (Table 19).

CEMENT

In 1916 Portland cement production and shipments in Illinois decreased sharply, occasioning a decrease in value of one and one-half million dollars (see Table 20). As elsewhere throughout the country production was on the increase, the Illinois loss of production meant loss of rank, ninth place in 1916 as compared with third in 1914 and 1915.

There were four producing and four shipping plants in the State in 1916, located at Oglesby (2), La Salle, and Dixon. Hitherto for a number of years five plants had been in active operation, but in 1916 the number became four with the dismantling of Mill No. 2, the South Chicago plant of the Universal Portland Cement Company. Construction work was started on that plant in the latter part of 1898, and the first cement was produced as early as the spring of 1900. Production had ceased in March, 1914, but shipments continued into 1915. Two factors combined to cause the abandonment of the plant: the machinery became out of date, rendering the manufacturing cost practically prohibitive; and the space occupied by the plant was needed badly by the Illinois Steel Company, who constructed a duplexing plant upon the same ground immediately after dismantling was complete. The territory fed by this plant does not lack for a nearby supply, however, as just over the Illinois line in northwestern Indiana at Buffington, the same company has developed a plant which is more than capable of taking care of the need formerly supplied by the South Chicago plant. Thus, although a certain credit of production is lost to Illinois and gained by Indiana, the situation is scarcely affected so far as the consumers of the district are concerned.

TABLE 19.—*Analyses grouped for comparing*

Location	Operator or Owner	Authority	Calcium carbonate ($CaCo_3$)	Magnesium carbonate ($MgCo_3$)
				WESTERN
Adams County				
Marblehead	Marblehead Lime Co.	N. Gray Bartlett, Chi.	95.62	.82
do	do	Wm. Brady	97.40	1.40
Alexander County				
Thebes		Agricultural Experiment Station, Univ. of Illinois	99.62	1.18
Jackson County				
Grand Tower		Dept. of Chemistry, Univ. of Illinois	93.93	4.89
Madison County				
Alton	Alton Lime & Cement Co.	H. E. Tuttle, St. Louis	97.53	.44
do (north layer)	Harry Gissal Quarry Co.	R. W. Erwin, Granite City	97.81	1.35
do (south layer)	do	do	98.09	.94
Monroe County				
Columbia	Columbia Quarry Co.	Pittsburgh Reduction Co.	97.30	.48
Randolph County				
Menard	Southern Illinois Penitentiary	Agricultural Experiment Station, Univ. of Illinois	93.73	3.84
Red Bud	William's Quarry	Dept. of Chemistry, Univ. of Illinois	96.42	1.09
Rock Island County				
Milan		do	82.04	5.52
do		do	96.67	1.21
St Clair County				
Millstadt	Columbia Quarry Co.		98.43	.....
Union County				
Anna	Union Stone & Lime Co.	Dept. of Chemistry, Univ. of Illinois	95.64	2.13
Korndahl		do	92.46	2.97
				NORTHERN
Boone County				
Belvidere	Electric Stone Co.	W. W. Daniels, Univ. of Wisconsin	52.27	44.67
do	do	do	54.59	41.33
Cook County				
Chicago	Artesian Stone & Lime Co.	T. C. Hopkins, State College, Pa.	53.70	42.34
do	Chicago Union Lime Works Co.	J. Blodgett Britton, Warrenton, Va.	52.76	45.04
McCook	U. S. Crushed Stone Co.	Inland Steel Co.	55.30	43.95
Thornton	Brownell Improvement Co.	Dickman & Mackenzie.	52.44	43.66
Kankakee County				
Kankakee	Lehigh Stone Co.	Pittsburgh Testing Laboratory, Pittsburgh	46.18	35.05
LaSalle County				
Utica	Illinois Hydraulic Cement Mfg. Co.	Dept. of Chemistry, Univ. of Illinois	45.32	26.13
do	do	do	50.60	38.25
Lee County				
Dixon	Sandusky Portland Cement Co.	do	81.79	9.57
do		do	65.98	23.45
Ogle County				
Grand Detour		do	86.36	11.41
Oregon		do	51.25	34.32
Stephenson County				
Winslow	City Quarry	do	46.71	33.90
Winnebago County				
Rockton	Rockton Lime & Quarry Co.	E. C. Eckel	51.33	37.33

[1] These analyses were taken from and others may be found in State Geological Survey Bulls. 4, 8, 16, and 17; and U S. Geological Survey Mineral Resources, Pt. II, 1911. The analyses credited to the Department of Chemistry and the Agricul-

northern Illinois with western Illinois limestones[1]

Ferric oxide (Fe_2O_3)	Aluminum oxide (Al_2O_3)	Silica (SiO_2)	Other minerals	Total	System and formation
ILLINOIS					
2.18		.47	Undetermined, 0.91...	100.00	Mississippian
.12	.68	.40	....	100.00	Mississippian
.32		.27	H_2O, .01............	......	Ordovician (Kimmswick)
.72		.86	H_2O, 0.07...........	......	Devonian (New Scotland)
.16		.48	H_2O and loss, 1.48...	100.09	Mississippian
Trace	....	1.00	....	100.16	Mississippian
Trace	....	.50	....	99.53	Mississippian
.44		1.12	....	100.00	Mississippian
1.11		2.47	H_2O, .105...........	......	Mississippian (Chester)
2.00		1.50	H_2O, .13............	......	Mississippian (Chester)
4.32		6.98	....	......	Devonian (Hamilton)
1.16		1.66	....	......	Devonian (Hamilton)
1.40		.90	....	100.08	Mississippian
.92		1.76	H_2O, 0.12...........	......	Mississippian (Salem)
1.48		3.30	H_2O, 0.10...........	......	Mississippian (Burlington)
ILLINOIS					
.98		1.87	....	99.79	Silurian
.85		2.90	....	99.67	Silurian
1.04		1.28	....	98.36	Silurian
1.48		.21	H_2O and loss, 0.51...	100.00	Silurian
.20		.36	....	99.81	Silurian
.85		2.35	Organic matter, 0.60.	99.90	Silurian
1.19	4.28	10.78	H_2O and loss, 2.50; P, 0.02; S, trace......	100.00	Silurian
8.20		15.02	H_2O, .33.............	95.00	Ordovician (Lower Magnesian)
3.72		4.58	H_2O, .11............	97.26	Ordovician (Lower Magnesian)
2.58		5.10	H_2O, .25............	99.29	Ordovician (Platteville)
4.60		4.50	H_2O, .11............	98.64	Ordovician (Platteville)
1.56		1.38	H_2O, .19............	100.90	Ordovician (Platteville)
4.22		5.62	H_2O, .33............	95.74	Ordovician (Platteville)
3.52		14.02	H_2O, .12............	98.27	Ordovician (Platteville)
.79	1.05	6.39	H_2O, 1.01...........	99.83	Ordovician

tural Experiment Station of the University of Illinois were made from samples collected by members of the State Geological Survey staff.

Analyses of many limestones show that abundant low-magnesia supplies are available for Portland cement manufacture in the Ordovician, Mississippian, and Pennsylvanian rocks. Many Ordovician formations are so highly magnesian as to be classed as dolomitic limestones or even dolomites, but certain formations such as the one used by the Sandusky Portland Cement Company at Dixon in Lee County, have a magnesia content low enough to make them usable as an ingredient of cement. Locally the Pennsylvanian system has limestones of good quality, such as the La Salle limestone of the McLeansboro formation, utilized by the Oglesby and La Salle Portland cement manufacturers, or such as another limestone of the McLeansboro formation in Vermilion County that formerly supplied the South Chicago plant. The Mississippian system is a far richer source of low-magnesia limestones than any of the other systems outcropping in Illinois but as yet none is being used. The thickness in which they outcrop, their accessibility, and proximity to coal and to river and railroad transportation make of them a valuable resource for future utilization. Figure 4 shows graphically the distribution of low-magnesia limestones for which analyses are available.

Besides Portland cement, natural cement is manufactured in the State at Utica. An Ordovician limestone, more specifically a horizon in the Prairie du Chien or "Lower Magnesian" limestone, is used. In this

TABLE 20.—*Portland cement industry in Illinois, 1900-1916*
(Figures opposite P relate to production; those opposite S to shipments.)

Year		Number of plants	Quantity	Value	Average price per barrel
			Barrels		
1900	P	3	240,442	$ 300,552	$1.25
1901	P	4	528,925	581,818	1.10
1902	P	4	767,781	977,541	1.27
1903	P	5	1,257,500	1,914,500	1.52
1904	P	5	1,326,794	1,449,114	1.09
1905	P	5	1,545,500	1,741,150	1.13
1906	P	4	1,858,403	2,461,494	1.33
1907	P	5	2,036,093	2,632,576	1.29
1908	P	5	3,211,168	2,707,044	.84
1909	P	5	4,241,392	3,388,667	.80
1910	P	5	4,459,450	4,119,012	.90
1911	P	5	4,582,341	3,583,301	.79
1912	P	5	4,299,357	3,212,819	....
	S	5	4,602,617	3,444,085	.75
1913	P	5	5,083,799	5,109,218	....
	S	5	4,734,540	4,784,696	1.01
1914	P	5	5,401,605	5,007,288	....
	S	5	5,284,022	4,848,522	.92
1915	P	4	5,156,869	....	....
	S	5	5,435,655	4,884,026	.90
1916	P	4	3,642,563	....	....
	S	4	3,562,659	3,386,431	.95

rock the composition approximates very closely that used in the mixture for Portland cement. The Utica plant is one out of but 12 natural cement plants in the country, and indeed is one of the first in the United States, its date of establishment, 1838, being later than only two other plants, in New York and in Kentucky, dating from 1818 and 1829, respectively.

SAND AND GRAVEL

For three years Illinois has reported a larger production of sand and gravel than has any other State, New York having been displaced from first rank in 1914. In 1916, Ohio, Indiana, New York, and Pennsylvania followed Illinois in the order given. In value of production, however, Illinois continues to stand fourth, Pennsylvania, Ohio, and New York reporting greater values.

Glass-sand production suffered decrease in quantity, but its value increased. Gravel, engine sand, paving sand, and fire or furnace sand all suffered greater or lesser decreases in quantity, but the increased production of molding, building, grinding and polishing sands was an offset sufficient to bring about an increase in the aggregate production of all kinds of sand and gravel amounting to 11.73 per cent for quantity, and 3.29 per cent for value, in 1916, as compared with the preceding year.

Of the forty-four counties reporting production, the leaders were La Salle, first in both quantity and value; Kane, second in quantity and third in value; Will, third in quantity and second in value; Winnebago, fourth in quantity and fifth in value; and Cook, fifth in quantity but fourth in value. With the exception of La Salle County, where the St. Peter sandstone is quarried, these counties all owe their high rank to their favorable location with reference to the glacial deposits of Wisconsin age, containing as they do great quantities of clean, unweathered gravel and sand.

Glass sand is derived in Illinois from the exceedingly pure, friable St. Peter sandstone outcropping in upper Illinois-Fox Valley and Rock River Valley; at Utica, Ottawa, Wedron, Seneca, Millington, and Oregon, all in these two valleys, six quarries and pits reported production of glass sand in 1916.

The factors[1] which determine the value of a deposit for making glass are chemical purity, physical character, quarrying conditions, and location with respect to transportation, cheap fuel, and market.

Glass is a transparent impermeable substance formed by fusing sand, or silica, with fixed alkalies. It is made by melting the ingredients in a pot or tank, mixing the batch thoroughly, and allowing it to cool. It is molded into the desired form while molten. Sand is the principal constituent of all glass, comprising from 52 to 65 per cent of the mass of the

[1] Burchard, Ernest F., Glass sand, other sand, and gravel: U. S. Geol. Survey Mineral Resources, 1911, pt. II, pp. 594-595, 1912.

TABLE 21.—*Production in short tons and values of different kinds of sand and gravel in Illinois, 1904-1916*

Year	Glass sand		Molding sand		Building sand		Grinding and polishing sand		Fire and furnace sand	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1904	219,784	$143,954	574,488	$363,090	338,461	$148,911	....	....	44,360	$19.751
1905	234,391	146,605	336,247	189,423	244,297	111,212	....	....	13,307	5.312
1906	238,178	156,684	372,307	216,087	868,014	314,071	....	....	87,560	38,466
1907	235,716	152,619	372,884	237,119	1,067,776	419,450	....	....	22,668	15,017
1908	194,722	139,172	143,080	86,213	1,342,303	481,827	....	....	75,762	19,799
1909	224.381	153,226	288,518	143,922	1,917,915	632,273	....	....	25,210	15,173
1910	268,654	216,531	407,232	215,742	1,756,652	473,209	....	....	97,633	60,932
1911	251,907	171,978	237,359	120,690	1,875,814	691,846	59,880	$41,765	62,107	25,643
1912	323,467	225.434	540,728	268,521	1,910,911	598,884	67,040	49,196	(a)	(a)
1913	350,229	239,227	404,717	181,794	2,299,834	594,687	42,198	23,138	84,801	43,269
1914	339,551	246,803	347,543	200,011	1,996,873	383,209	58,351	38,780	60,674	24,569
1915	566,128	299,286	383,185	195,992	1,600,521	472,654	(a)	(a)	(a)	(a)
1916	487,432	318,235	632,529	313,219	2,059,259	597,771	168,088	152,432	(a)	(a)

Year	Engine sand		Paving sand		Other sands		Gravel		Total	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1904	8,250	$2,120	....	....	21,328	$11,914	....	....	1,206,671	$689,740
1905	4,062	1,425	....	....	518,049	112,761	277,050	$127,034	1,627,403	693,772
1906	70,000	27,400	....	....	64,903	32,068	956,597	258,265	2,657,559	1,043,041
1907	113.742	29,091	....	....	940,746	133,090	1,797,459	381,237	4,550,991	1,367,653
1908	47,863	8,952	....	....	2,047,147	175,941	2,806,871	591.118	6,657,748	1,503,022
1909	104,882	11,242	....	....	3,188,885	277,056	3,405,438	716,605	9,155,229	1,949,497
1910	43.147	6,840	....	....	1,211,564	130,756	4,801,626	626,785	8,586,508	1,730,795
1911	46,897	6,158	318,671	$125,624	1,862,000	164,292	3,774,048	642,926	8,488,683	1,990,922
1912	59,151	12,916	30,581	13,958	499,685	75,391	3,481,638	664,552	6,957,901	1,929,822
1913	79,568	11,166	101,631	30,973	171,898	77,252	4,457,264	868,985	7,992,140	2,070,491
1914	93,299	12,239	121,812	39,851	522,808	120,635	4,955,219	793,422	7,696,130	1,859,519
1915	73,427	14,677	291,436	73,645	8,376	4,402	4,424,527	885,548	7,708,012	1,984,569
1916	67,979	12,143	90,843	32,803	1,500,942	312,887	3,358,153	847,947	8,365,225	2,587,437

a Concealed in "Total."

original mixture. The qualities of the glass, such as lack of color, brilliance, transparency, and hardness, depend largely, therefore, on the quality of the sand.

For the finest ware only the purest quartz (silica) sand can be employed because slight impurity, especially a small quantity of iron, impairs the brilliance, whiteness, and clearness. Thus, for the manufacture of glass for optical instruments, which is practically colorless, sand, or ground silica, should contain, not more than 0.015 per cent of ferric oxide. Plate and window glass are commonly pale green and absolute purity is not essential in the sand, but more than 0.2 per cent of ferric oxide is undesirable. Green and amber glass for rough structural work, as skylights, sidewalk lights, for bottles, jars, and insulators, are made from sand that has more impurity than is permissible in sand for plate glass and prescription ware.

The suitability of a sand for making glass may be determined roughly by inspecting it for the following properties: The sand should consist almost entirely of quartz, or silica (most glass sands contain from 98 to more than 99 per cent of silica); it should be nearly white or easily washed white; the grains should be uniform in size, either angular or rounded, and preferably should not be larger than 20 mesh nor smaller than 80 mesh. Whiteness is not essential, however, in sand for ordinary window glass and cheap bottles and jars.

As shown by the following analyses (Table 23), the Illinois glass sand not only conforms well to the requirements outlined above, but compares favorably with that from other states.

Clearly it is not in the chemical character of the sand that an explanation of the low value of the Illinois product as compared with the average for the country (see Table 24) is to be found. Comparing Pennsylvania and Illinois prices, an even greater difference is found, slightly more than $1.18 being the price of the eastern sand, and $0.65 of the Illinois product, a relation which is typical for earlier years as well. In part the difference is to be accounted for by the fact that the Pennsylvania sand is somewhat more expensive to produce, being made from harder rock; and for this reason a sharper, even-grained, and consequently a slightly more desirable glass sand results. But the more important factor is that as the Pennsylvania and other eastern sands are all consumed at or near the point of origin, prices there are largely controlled by the production cost of Illinois and Missouri sand plus freight charges to the east, rather than the production cost of eastern sands plus the negligible freight charges required for their local distribution.

TABLE 22.—*Production in short tons, and value of sand*

1915

County	Producers	Glass sand		Molding sand		Building sand		Grinding and polishing sand		Fire or furnace sand
		Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity
Bond	6	...	...	18,387	$14,902	3,700	$1,395	...	...	...
Bureau	8	...	...	(a)	(a)	(a)	(a)	...	...	...
Carroll	3	...	...	...	...	(a)	(a)	...	...	...
Cook	4	...	...	...	...	194,336	107,475	...	...	...
Kane	10	...	...	23,169	11,584	393,402	75,209	...	...	...
Lake	3	...	...	...	...	(a)	(a)	...	...	...
La Salle	18	495,884	$251,552	260,207	115,168	(a)	(a)	62,366	$26,370	(a)
Lee	6	...	...	...	...	6,900	1,800	...	...	...
McHenry	5	...	...	(a)	(a)	41,745	15,482	...	...	...
Madison	3	...	...	(a)	(a)	(a)	(a)	...	...	...
Ogle	5	(a)	(a)	...	...	(a)	(a)	...	...	...
Peoria	10	...	...	...	...	41,710	23,700	...	...	...
Rock Island	7	...	...	(a)	(a)	110,390	28,508	...	...	...
Tazewell	4	...	...	...	...	43,338	11,780	...	...	...
Whiteside	7	...	...	(a)	(a)	(a)	(a)	...	...	...
Will	5	...	...	(a)	(a)	10,305	3,950	...	...	...
Winnebago	6	...	...	(a)	(a)	(a)	(a)	...	...	...
Other counties[b]	20	2,500	2,125	28,999	13,975	385,100	105,899	...	...	...
State total	127	566,128	$299,286	383,185	$195,992	1,600,521	$472,654	62,366	$26,370	(a)

[a] Concealed in totals.
[b] Including: Alexander, Boone, Cass, Dekalb, Dupage, Fayette, Fulton, Henderson, White counties.

1916

County.	Producers.	Glass sand		Molding sand		Building sand		Grinding and polishing sand		Fire or furnace sand
		Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity
Bond	5	...	...	30,858	$ 26,180	...	...	(a)	(a)	...
Bureau	9	...	...	(a)	(a)	25,471	$ 2,669	...	...	...
Carroll	4	...	...	...	...	1,215	200	...	...	...
Cook	3	...	...	...	...	(a)	(a)	...	...	...
Kane	15	...	...	33,091	15,068	530,671	112,653	...	...	...
Kendall	3	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	...
Lake	3	...	...	...	...	(a)	(a)	...	...	...
La Salle	21	391,524	$257,170	469,829	201,448	7,924	4,431	164,110	$149,532	19,623
Lee	3	...	...	...	...	(a)	(a)	...	...	...
McHenry	9	...	...	11,669	6,122	113,841	34,604	...	...	...
Macon	3	...	...	...	...	(a)	(a)	...	...	...
Madison	4	...	...	(a)	(a)	(a)	(a)	...	...	...
Ogle	5	(a)	(a)	...	...	...	...	...	...	...
Peoria	9	...	...	(a)	(a)	71,924	28,903	...	...	...
Rock Island	8	...	...	(a)	(a)	63,378	20,293	...	...	...
Tazewell	3	...	...	...	...	(a)	(a)	...	...	...
Whiteside	5	...	...	(a)	(a)	(a)	(a)	...	...	...
Will	9	...	...	33,685	18,973	60,951	17,486	...	...	...
Winnebago	10	...	...	(a)	(a)	...	...	...	...	(a)
Other counties[b]	31	...	...	6,268	5,753	490,650	120,792	1,628	1,200	...
State total	131	487,432	$318,235	632,529	$313,219	2,059,259	$597,771	168,088	$152,432	(a)

[a] Concealed in totals.
[b] Including: Alexander, Boone, Cass, Dekalb, Dupage, Fayette, Fulton, Henderson, White counties.

and gravel in Illinois, by counties, 1915 and 1916

Fire or furnace sand	Engine sand		Paving sand		Other sands		Gravel		Total	
Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
....	(a)	(a)	(a)	(a)	....	....	(a)	(a)	23,594	$ 17,399
....	(a)	(a)	....	....	....	....	65,771	$ 21,111	84,221	26,504
....	....	....	(a)	(a)	....	....	4,153	1,328	5.548	2,453
....	....	....	....	....	....	....	547,991	96,325	742,327	203,800
....	....	....	....	....	1,500	$ 200	349,273	147,296	767,344	234,289
....	....	....	....	....	....	....	208,640	37,208	343.640	71,208
(a)	(a)	(a)	....	....	5,000	3,000	20,513	9,519	1,160,266	429,054
....	....	....	(a)	(a)	....	....	7,221	1,925	14,621	3,825
....	....	....	....	....	....	....	(a)	(a)	58,194	23,605
....	....	....	....	....	1,500	1,125	....	....	95,046	26,194
....	....	....	(a)	(a)	....	....	321,415	23,325	398,909	72,534
....	....	....	(a)	(a)	....	....	154,966	55,200	196,946	78,980
....	....	....	....	....	....	....	72,253	20,711	185,867	51,882
....	....	....	72,255	$21,834	....	....	(a)	(a)	234,599	77,934
....	(a)	(a)	(a)	(a)	....	....	69,615	28,590	98,646	36,977
....	....	....	....	....	....	....	....	....	33,234	15,926
....	....	....	(a)	(a)	....	....	2,091,145	297,510	2,368.515	371,313
....	49,002	$6,471	43,755	12,495	376	77	386,763	99,640	886,495	240,682
(a)	73,427	$14,677	291,436	$73,645	8,376	$4,402	4,424,527	$885,548	7,708,012	$1,984,569

Jo Daviess, Kendall, Logan, Menard, Mercer, Monroe, Pike, St. Clair, Sangamon, Wabash, and

Fire or furnace sand	Engine sand		Paving sand		Other sands		Gravel		Totals	
Quality	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
....	....	....	(a)	(a)	....	....	....	....	32,343	$ 26,420
....	....	....	....	....	9,930	$ 1,456	97,260	$ 17,491	136,371	24,416
....	....	....	....	....	....	....	(a)	(a)	1,746	284
....	....	....	....	....	(a)	(a)	(a)	(a)	724,304	217,335
....	....	....	(a)	(a)	32,250	7,600	525,352	116,758	1,126,509	255,279
....	....	....	....	....	....	....	(a)	(a)	100,276	37,356
....	....	....	....	....	(a)	(a)	(a)	(a)	269,763	63,278
8,230	(a)	(a)	....	....	(a)	(a)	359,620	29,032	1,426,536	677,376
....	....	....	....	....	....	....	3,975	1,610	7,425	3,210
....	....	....	(a)	(a)	....	....	262,498	52.342	413,808	100,518
....	....	....	....	....	....	....	37,506	28,527	37,859	28,664
....	....	....	....	....	....	....	(a)	(a)	92,093	35,395
....	....	....	....	....	(a)	(a)	1,287	146	347,070	95,191
....	....	....	24,164	$ 10,575	....	....	179,882	39,322	276,344	78,945
....	....	....	(a)	(a)	(a)	(a)	121,650	70,855	212,397	107,195
....	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	306,413	105,592
....	....	....	(a)	(a)	....	....	(a)	(a)	23,935	12,256
....	....	....	....	....	439,534	93,824	(a)	(a)	1,099,164	293,781
(a)	....	....	....	....	(a)	(a)	416,317	69,265	733,164	165,497
....	61,695	9,019	18,342	4,565	195,355	26,906	215,067	86,206	990.005	254.441
(a)	67,979	$12,143	90,843	$32,803	1,476,504	$302,557	3,358,153	$847,947	8,365,225	$2,587,437

Jo Daviess, Kendall, Logan, Menard, Mercer, Monroe, Pike, St. Clair, Sangamon, Wabash, and

TABLE 23.—*Analyses of ten glass sands quarried in the Mississippi Basin and in eastern United States*

Location of mine or quarry	Operator	Silica (SiO_2)	Magnesia (MgO)	Lime (CaO)	Iron Oxide (Fe_2O_3)	Alumina (Al_2O_3)	Other minerals	Total	Authority
Illinois									
Ottawa, La Salle County..........	Ottawa Silica Co.	99.45	Trace	0.13	0.30		....	99.88	Prof. R. E. Lyons, Indiana University, Bloomington, Ind.
South Ottawa, La Salle County.....	United States Silica Co.	99.89	0.01	.00	Trace	0.051	....	99.951	R. W. Hunt and Co., Chicago, Illinois
Wedron, La Salle County..........	Wedron White Sand Co.	99.89	.01	.00	......	.051	....	99.951	Cary and Moore, Chicago. Ill.
Utica, La Salle County............	E. J. Reynolds Sand Co.	99.576	.002	.0197	.0903	.283	....	99.971	Operators of quarry.
Missouri									
Klondike, St. Charles County.....	Tavern Rock Sand Co.	99.97	......	.03			Loss, etc., .17, cobalt, none	100.	Regis Chauvenet and Bro., St. Louis. Mo.
Pennsylvania									
Columbia..........................	....	99.504	.....	......	.299	.134	Loss, etc., .062	99.999	
Mapleton Depot, Huntington County	Pennsylvania Glass Sand Co,	99.70	Trace	Trace	.026	.24	....	99.966	Booth, Garrett and Blair, Philadelphia, Pa.
Derry, Westmoreland County......	Derry Glass Sand Co.	99.65	.03	.02	.11	.17	....	99.98	E. S. Brown, Latrobe, Pa.
West Virginia									
Hancock, Morgan County..........	Pennsylvania Glass Sand Co.	99.889	......	.011	.006	.094	....	100.	Otto Wuth, Pittsburgh, Pa.
Berkeley Springs, Morgan County.	Berkeley Sand Co.	99.37	......	......	.04	.33	....	99.91	Pittsburg Testing Laboratory, Pittsburgh, Pa.

TABLE 24.—*Glass sand produced in Illinois, 1903-1916*

Year	Quantity	Value	Average price per ton	
			Illinois	*United States*
1903	255,440	$153,717	$0.60	$1.04
1904	219,784	143,954	.66	.90
1905	234,391	146,605	.63	1.05
1906	238,178	156,684	.66	1.11
1907	235,716	152,619	.65	1.05
1908	194,722	139,172	.71	.96
1909	224,381	153,226	.69	1.05
1910	268,654	216,531	.81	1.04
1911	251,907	171,978	.68	1.01
1912	323,467	225,434	.70	.97
1913	350,229	239,227	.68	1.06
1914	339,551	246,803	.73	.97
1915	566,128	299,286	.53	.85
1916	487,432	318,235	.65	.97

FLUORSPAR

Illinois continued as leader in production of fluorspar in 1916, a position which it has held since 1905 and from which it will doubtless never

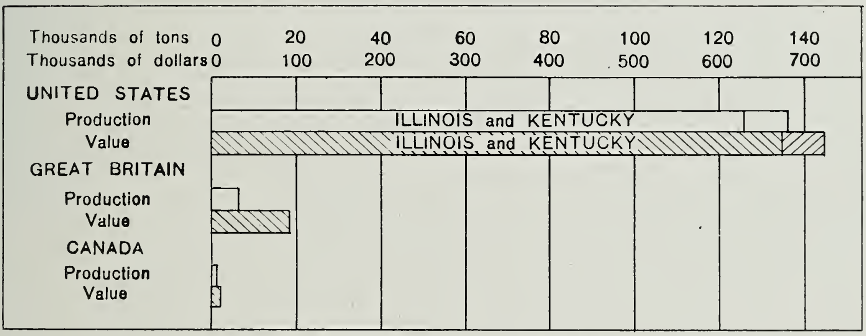

FIG. 5.—Diagram showing the output and value of fluorspar from the Illinois-Kentucky district, the United States, and other producing countries of the world, 1916.

be forced, according to our present knowledge of the fluorspar deposits. Other deposits are known, and some of them are worked in the United States, but none can rival those of the Illinois-Kentucky district, centering in southern Hardin County, Illinois. Figure 5 shows graphically the relative importance of the district in the United States, and gives also a striking comparison between our production and that of the other producing countries of the world.

TABLE 25.—*Domestic fluorspar sold, 1913-1916*

State	Gravel			Lump			Ground			Total		
	Quantity (short tons)	Value	Average price per ton	Quantity (short tons)	Value	Average price per ton	Quantity (short tons)	Value	Average price per ton	Quantity (short tons)	Value	Average price per ton
1913												
Illinois	} 91,663	$525,456	$5.73	5,676	$ 39,059	$6.88	8,137	$100,203	$12.31	{ 85,854	$550,815	$6.42
Kentucky	}									{ 19,622	113,903	5.80
Other States[a]	[b]10,104	71,568	7.08	([b])	([b])	.....	......	....	......	10,104	71,568	7.08
	[b]101,767	597,024	5.87	[b]5,676	39,059	6.88	8,137	100,203	12.31	115,580	736,286	6.37
1914												
Illinois	} 77,048	397,913	5.16	8,842	74,708	8.45	6,998	82,428	11.78	{ 73,811	426,063	5.77
Kentucky	}									{ 19,077	128,986	6.76
Other States[a]	[b]2,228	14,992	6.73	([b])	([b])	.....	......	....	......	2,228	14,992	6.73
	[b]79,276	412,905	5.21	[b]8,842	74,708	8.45	6,998	82,428	11.78	95,116	570,041	5.99
1915												
Illinois	} 112,769	547,415	4.85	12,033	90,337	7.51	10,757	116,161	10.80	135,559	753,913	5.56
Kentucky	}											
Other States[a]	[b]1,382	10,562	7.64	([b])	([b])	.....	......	....	......	1,382	10,562	7.64
	[b]114,151	557,977	4.89	[b]12,033	90,337	7.51	10,757	116,161	10.80	136,941	764,475	5.58
1916												
Illinois	} 123,983	660,714	5.33	14,489	114,993	7.94	7,595	94,039	12.38	146,067	869,746	5.95
Kentucky	}											
Other States[a]	[b]9,668	52,908	5.47	([b])	([b])	.....	......	....	......	9,668	52,908	5.47
	[b]133,651	713,622	5.34	14,489	114,993	7.94	7,595	94,039	12.38	155,735	922,654	5.92

[a] Includes, 1913: Arizona, Colorado, New Hampshire, and New Mexico; 1914: Colorado and New Hampshire; 1915: Colorado, New Hampshire, and New Mexico; 1916: Arizona, Colorado, and New Hampshire.

[b] Some lump spar is included with gravel.

The market for the bulk of the fluorspar sold in the United States depends on the steel industry, and the demand fluctuates with the rise and fall in the production of steel. Fluorspar is however not confined in its use to the steel industry, but finds a place also as a flux in iron blast furnaces and foundries, and in lead, copper, gold, and silver smelters; in the manufacture of fluorides of iron and manganese for steel fluxing, and of sodium fluoride for wood preservation; in the manufacture of glass, of enameled and sanitary ware, and of hydrofluoric acid; in the electrolytic refining of antimony and lead; and in the production of aluminum. Other miscellaneous uses of fluorspar that have been reported are as a bonding for constituents of emery wheels, for carbon electrodes, in the extraction of potash from feldspar, and in the recovery of potash in the manufacture of Portland cement.

Noteworthy features of the industry in 1916 were the continued strong demand and increased prices which culminated at the end of the year in a shortage of spar that forced prices for prompt shipment to an unprecedented level. Under the stimulus of high prices, abandoned prospects were reopened in southern Illinois and western Kentucky and should be expected to make an appreciable contribution to the 1917 production. The output in Illinois was higher than ever before and doubtless would have been greater had not the mines been shut down for part of July on account of miners' strikes. For a time the situation threatened to become serious, as the Illinois mines customarily produce 75 to 80 per cent of the domestic output.

MINERAL WATER

The production of mineral water in Illinois increased 14 per cent in quantity and 25 per cent in value in 1916. The output of both medicinal and table waters increased appreciably. The total sales were 1,777,741 gallons, valued at $94,056, of which $7,765 was received for medicinal waters and $86,291 for table waters. The number of active springs decreased from 23 to 21.

The quantity of mineral water used in the manufacture of soft drinks decreased from 267,880 gallons to 106,340 gallons. Resorts for about 750 guests were maintained at five springs, and mineral-water bathing establishments were maintained at nine springs, the same as in 1915.

TRIPOLI

Tripoli and quartz—the two forms of silica mined in Illinois—were both produced in greatly increased amounts in 1916 as compared with 1915.

Four mines in Union County and two in Alexander County reported production of tripoli in 1916. No new deposits were developed but there were several changes in ownership or management and greatly increased activity and production. A number of mines formerly worked were idle. Crude material, as in 1915, had an average value of about $2.50 a ton. Most of the output was, however, sold in ground form at $17 to $25 a ton.

TABLE 26.—*Tripoli produced and sold in the United States, 1914-1916*

State	1914		1915		1916	
	Quantity (short tons)	Value	Quantity (short tons)	Value	Quantity (short tons)	Value
Illinois	10,387	$59,394	23,756	[a] $59,390	33,187	$ 82,968
Missouri	6,721	81,434	6,955	69,567	10,070	132,248
Other States[b]	110	1,600				
	17,218	142,428	30,711	128,957	43,257	215,216

[a] Value for 1915 revised in 1916.
[b] 1914, Oklahoma and Pennsylvania; 1915, Pennsylvania and Georgia; 1916, Pennsylvania and Oklahoma.

The detailed geology of the tripoli region has not yet been studied, but the following statement regarding the occurrence, geology, mining methods and uses of the tripoli has been prepared as a general answer to the inquiries which are frequently received by the Survey.

The tripoli occurs as rather distinct beds in the flat or gently dipping formation in the hills above the flood plain of the Mississippi. The region is rugged, due to erosion which exposes the silica formations above drainage level.

Devonian fossils of Upper Oriskany age (Clear Creek chert) may be readily found, thus fixing the age of the beds. The layers of tripoli are from a few inches to a few feet in thickness, somewhat interbedded with layers of chert or flint of similar thicknesses. The tripoli is colorless or white in appearance except where stained faint buff or yellowish by iron. It is friable or "soft" to the touch. It probably represents the siliceous "skeleton" of a former bed of siliceous limestone or cherty limestone from which the soluble portions have now been removed by decomposition and solution due to percolating waters.

Mining methods consist of opening a drift or adit and driving irregular rooms protected by large pillars. Rooms 10 feet high are not un-

common. It is the practice to drive teams and ordinary wagons into the mine for loading and hauling to the nearest mill. The tripoli and interbedded flint is mined with pick and shovel, and only a little explosive is used.

When the tripoli reaches the mill it passes through coarse crushers or disintegrators and screening devices which remove the flint and chert from the tripoli. The latter is further disintegrated by tube mills, hammer mills, or other types of grinding apparatus, and is carefully sized by either air-float or water-float methods. The finest material easily passes a 300-mesh screen and ground tripoli, although essentially pure silicon dioxide, feels almost as velvety as talc powder.

The principal plants and shipping points have been located at Jonesboro, Tamms, Thebes, Reynoldsville, and Wolf Lake. Recent increases in development work have been reported, and the statement above is therefore only of general value.

Because of the check on importation due to the war this country was forced to look to its own silica supplies, and it was found that the tripoli beds of southern Illinois were a very satisfactory substitute for the imported French chert used in the manufacture of high-grade white ware. The remarkably pure St. Peter sandstone from the vicinity of Ottawa is also used somewhat, but even when finely ground is not so well adapted for this purpose as is the amorphous silica or tripoli of southern Illinois. The increased production of silica during recent years is in part the result of increased demand due to this new use. A great variety of uses outside the pottery business, most of them recognized for some time, are as follows: paint, wood filler, metal polish, in soaps, cleansers, glass manufacture, and for facing foundry molds.

Although not to be classed as tripoli or even under the more inclusive term silica, mention should be made here of the great "novaculite" hills near Tamms, Illinois, which annually afford large quantities of material for road construction. Geologically the "novaculite" deposits are of the same age and origin as the purer tripoli deposits. Unlike the true novaculite of Arkansas which is used for oil stones, the Illinois "novaculite" is largely interbedded chert, silica, and clay which when crushed forms a successful road surface, if the condition of novaculite roads in southern Illinois, laid about the beginning of the century, is any criterion.

PYRITE AND SULPHURIC ACID

In 1916 production so far recovered from the decrease of 1915 as to almost equal that of 1914. Illinois continued to rank fourth in both quantity and value of pyrite marketed in 1916. The 20,482 tons pro-

duced, valued at more than $50,000, was all won in the course of coal-mining operations. The pyrite, or more exactly marcasite, found in association with coal beds was formerly thought to be worthless or injurious material that must be discarded. With the recognition during the past few years of its considerable value, which was further enhanced by the extraordinary war need of sulphuric acid, it was found that an appreciable profit could be made in certain localities and a cleaner, better coal would result by separation of the "sulphur". With improvement and perfection of methods of separation, still further saving and utilization may be expected.

Ten mines reported production; eight, Hume and Spangler, Danville Collieries Coal Company, Central Coal Company, Western Coal Company, Contract Mining Company, Wm. J. Watkins, Carbon Hill Coal Company, and Edward Evans, in Vermilion County; one, the Madison Coal Corporation, in Madison County; and one, the J. H. Milan mine, in Knox County. Table 27 gives the production of pyrite for the years 1909 to 1916. Earlier reports of production combined totals for Indiana with those for Illinois.

The sulphuric acid produced in Illinois is a by-product in the smelting of zinc in which processes the waste gases, sulphur dioxide, and sulphur trioxide, are converted into acid. Most of the sulphuric acid is used in the manufacture of fertilizers; the refining of petroleum products; the iron, steel, and coke industries; the manufacture of nitrocellulose, nitroglycerin, celluloid, etc.; and general metallurgic and chemical practice.

TABLE 27.—*Production in long tons and value of pyrite mined in Illinois, 1909-1916*

Year	Quantity	Value	Average price per ton
1909	5,600	$17,551	$2.60
1910	8,541	28,159	3.30
1911	17,441	47,020	2.70
1912	27,008	62,980	2.33
1913	11,246	31,966	2.84
1914	22,538	59,079	2.62
1915	14,849	22,476	1.51
1916	20,482	51,432	2.51

LEAD, ZINC, AND SILVER

The lead and zinc deposits of Illinois fall into two distinct regions marked by different mineral association and structural environment. Those of southern Illinois belong to the Kentucky-Illinois fluorspar dis-

trict; those of northern Illinois belong to the upper Mississippi Valley region.

Northern Illinois.—The lead and zinc mines of northern Illinois are all in Jo Daviess County, the extreme northwest county of the State. The ore deposits occur in the Galena dolomite and in the upper part of the Platteville limestone, both of Ordovician age. They are galena, smithsonite, and sphalerite, though the two latter are much less common now than formerly, when the deposits worked were mostly shallow and above water level. In early years the galena ores only were mined and the ore was taken from shallow pockets in quantities ranging from a few tons to several thousand.

Although the lead output of northern Illinois, Wisconsin, and Iowa has been large in the past, and the ores have been smelted near the mines, the output in recent years has been comparatively small, and no ores have been smelted in those states. The galena is practically nonargentiferous, and the zinc ores are not known to contain cadmium. Iron pyrites is very commonly associated with the ores, frequently in such quantity as to necessitate roasting and magnetic separation.

TABLE 28.—*Tenor of lead and zinc ore and concentrates produced in Illinois, 1915 and 1916*

	1915	1916
NORTHERN ILLINOIS		
Total crude ore........short tons..	316,000	288,100
Total concentrates in crude ore:		
Lead ....per cent..	0.22	0.23
Zinc ....do....	6.5	5.28
Metal content of crude ore:		
Lead ....do....	.17	.16
Zinc ....do....	2.18	1.44
Average lead content of galena concentrates........do....	72.9	68.2
Average zinc content of sphalerite concentrates........do....	33.5	27.4
Average value per ton:		
Galena concentrates	$47.27	$69.30
Sphalerite concentrates........	$36.73	$30.31
SOUTHERN ILLINOIS		
Average lead content of galena concentrates........per cent	71.6	70.0
Average value per ton of galena concentrates........	$43.45	$76.38

The largest production of lead and zinc concentrates in northern Illinois in 1916, as in 1914 and 1915, was derived from the old Marsdon-Black Jack mine of the Mineral Point Zinc Company. The mill was steadily operated during 1916 on dirt obtained by means of two shafts, one of which is 200 feet and the other 250 feet deep. The mill has a capacity of 600 tons in 24 hours.

Southern Illinois.—The lead and zinc deposits of southern Illinois are found in Pope and Hardin counties in rocks of Mississippian age in the northern extension of the Kentucky-Illinois fluorspar district.

The principal product of the mines in recent years has been fluorspar, and the yield of galena is small compared with the output from other districts in the Central States. The total production of galena concentrates

TABLE 29.—*Production and value of lead, zinc, and silver in Illinois, 1909-1916*

Year	District	Lead		Zinc		Silver	
		Quantity	Value	Quantity	Value	Quantity	Value
		Short tons		*Short tons*		*Fine ounces*	
1909	Northern Illinois..	88	7,566	2,163	223,604	.....	.....
	Southern Illinois..	207	17,804	.....	....	1,011	526
	Total........	295	25,370				
1910	Northern Illinois..	101	8,888	3,549	383,292	.....	.....
	Southern Illinois..	272	23,936	.....	....	2,022	1,092
	Total........	373	32,824				
1911	Northern Illinois..	625	56,250	4,219	480,966	.....	.....
	Southern Illinois..	339	30,510	.....	....	3,036	1,609
	Total........	964	86,760				
1912	Northern Illinois..	687	61,830	4,065	560,970	.....	.....
	Southern Illinois..	595	53,550	.....	....	4,731	2,909
	Total........	1,282	115,380				
1913	Northern Illinois..	588	51,744	2,236	250,432	.....	.....
	Southern Illinois..	371	32,648	......	....	3,541	2,139
	Total........	959	84,392				
1914	Northern Illinois..	492	38,376	4,811	490,722	.....	.....
	Southern Illinois..	225	17,550	.....	....	2,112	1,168
	Total........	717	55,392				
1915	Northern Illinois..	495	46,530	5,534	1,372,432	.....	.....
	Southern Illinois..	459	43,146	.....	....	3,864	1,959
	Total........	954	89,676				
1916	Northern Illinois..	462	63,756	3,404	912,272	......	.....
	Southern Illinois..	610	84,180	.....	....	5,684	3,740
	Total........	1,072	147,936				

for southern Illinois, 1906 to 1916, inclusive, has been 5,319 tons, most of which has been shipped from the Fairview and Rosiclare mines. The shipments of zinc ores from the district have been comparatively small and scattered. The only recorded shipments of zinc carbonate were made from the Empire mine in 1903 or 1904, and in 1906 four companies made shipments aggregating 103 tons.

Formerly, and nearer the surface, large bodies of galena were worked, but it is at present produced incidentally in the concentration of the fluorspar. For this reason it would be misleading to give the quantity of crude ore. As the district is not reached by railway, the product of the mines is dependent on river transportation.

The galena of southern Illinois is notably argentiferous as compared with the rest of the Mssissippi Valley ores, the silver content ranging up to 12 and 14 fine ounces per ton of lead concentrates and averaging for the last seven years from 4 to 7 fine ounces per ton of lead concentrates. Sphalerite, or zinc blende, is the next important metallic mineral, but it occurs much less plentifully than galena. It is recovered as zinc middlings in the concentration of the fluorspar. The difficulty of making a clean separation of the zinc middlings has kept down the production of zinc. None has been sold from southern Illinois in the last eight years. The principal vein minerals are fluorspar, calcite, and barite.

MINERAL PAINTS

In 1916 as in the preceding year, pigments were made directly from the ore in Illinois only at Collinsville, at the plant owned by the St. Louis Smelting and Refining Company; sublimed white lead or "basic lead sulphate" and sublimed blue lead or "blue fume" were the two products there produced.

Chemically manufactured pigments were made at Chicago, Argo, and East St. Louis; white lead, red lead, and litharge at Chicago; lithopone at Argo; and white lead at East St. Louis. The total value for all these products was $7,654,700. Of this only the value of the Collinsville product was included in the total Illinois value of mineral products, as duplication would be involved if others were also included.

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CLAY DEPOSITS NEAR MOUNTAIN GLEN UNION COUNTY, ILLINOIS[1]

By Stuart St. Clair

OUTLINE

ILLUSTRATIONS

INTRODUCTION

Importance and Location of Clay Deposits

The existence of fire-clay deposits near Mountain Glen, Union County, Illinois, has been known for many years. Development on a very small scale was attempted at a few places, and small shipments were made from time to time. Not until the European war cut off importation of high-grade German refractory clays was the economic importance of the Union County fire clay generally recognized. This clay is reported to be equal, if not superior, to the foreign clay for the manufacture of graphite crucibles and glass pots.

There are at present three producing mines in the area, and a new industry has developed which, on account of the high grade of its product, should weather the storm of competition when it is again possible for the importation of European fire clays.

The area in which the clays are found is in the northwestern part of Union County, less than one mile southwest of Mountain Glen, which is

[1] First published in 1917, as an extract from Bull. 36.

on the Mobile and Ohio Railroad, and about six miles northwest of Anna. The three producing properties are located in the western half of sec. 35, T. 11 S., R. 2 W. Several prospects, an abandoned mine, and an intermittent producer are in the vicinity.

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GENERAL GEOLOGY

No attempt was made to study in detail the stratigraphy of the area. The section, however, includes Devonian, Mississippian, and Pennsylvanian formations. Black shales and cherts of Devonian age are present in the hills about half a mile west of the mines, a fault separating them from the Mississippian rocks which outcrop near the mines. At the big pit of the Illinois Kaolin Company, the Spergen limestone outcrops, being recognized by Weller by the presence of *Spirifer subcardiformis,* a characteristic fossil. To the north, the Chester and Pennsylvanian formations are typically developed, a northwest-southeast fault having dropped them down at a point a little northeast of the clay mines. To the south and southeast the Mississippian formations older than Chester are to be found.

In the extreme southern part of the State are deposits of sand and clay laid down in the "Gulf embayment" and assigned to Cretaceous-Tertiary time. Overlying these deposits are the sands and gravels that are referred to the Lafayette. The clay deposits of the area described in this report are thought to have been deposited in an arm of the Tertiary Gulf embayment, which extended farther north on the west side of the Paleozoic uplands than did the main embayment on the east side.

The major faulting of the region is post-Pennsylvanian in age and is thought to have taken place at about the close of the Paleozoic era. The even-crested tops of the Devonian hills west, southwest, and south of the clay mines, as well as the ridges of the Pottsville escarpment to the north and east, strongly suggest the former presence of the peneplain which may have reached its fullest development about Cretaceous time. On the hills west of the mines, chert gravels were found very sparsely distributed at elevations of more than 700 feet, and they may extend to a greater elevation.

Quaternary lake deposits are found in the valleys of the larger streams on two well-defined terraces, the higher of which does not exceed 400 feet. None of these deposits extends up Clear Creek as far as the clay mines, for the elevation at the latter is close to 450 feet.

Alluvium of Recent age is found in the flood-plain areas of the streams in the region.

CLAY DEPOSITS

Character

From a lithologic standpoint there are four kinds of clay in the area—a bluish-white, highly plastic fire clay; white, highly plastic fire clay; pink, highly plastic fire clay; and pink and white, less-plastic clays. The first two are the valuable commercial clays. All are very fine grained and contain no grit whatever except at the contacts with the underlying and overlying sands or near some sand pocket within the clay deposit.

Three samples of clay have been tested by the Ceramics Department, University of Illinois, under the supervision of Professor C. W. Parmelee. The results are tabulated below. Sample 1 is bluish-white clay taken at a depth of 58 feet from the surface, or 50 feet below the top of the clay. Sample 2 is bluish-white clay taken from a pit and was 30 feet below the top of the pink clay and 15 feet below the top of the bluish-white clay. Sample 3 is pink clay taken from the pit and was about 10 feet from the top of the clay.

Sample 1

Color	Bluish white
Plasticity	Very good
Water content required	32.8 %
Molding properties	Formed readily by hand and flowed easily through a die.
Tensile strength of dry briquets	124 pounds per square inch
Bonding strength, i. e., the tensile strength of a mixture of equal parts of clay and standard Ottawa sand	95.3 pounds per square inch
Slaking test, i. e., the time required for a mixture of equal parts of potter's flint and clay formed into ¾-inch cubes to disintegrate when submerged in water at room temperature	21 minutes

Screen test of clay defloculated by use of an appropriate amount of sodium carbonate gave the following residues—

200 mesh	0.53%
100 mesh	0.21
80 mesh	0.24
40 mesh	0.04
20 mesh	0.00
Total residue	1.02%

Drying shrinkage of the clay formed into bars by forcing plastic body through a die	6.7 %

Burning tests—

Cone	*Color*	*Hardness*	*Porosity*	*Shrinkage*
08	White	Scratched with knife	37.0%	2.75%
06	do	do	36.7	3.25
04	do	do	36.9	3.25
02	do	Steel hard	33.7	4.0
1	do	do	33.7	4.0
3	do	do	23.0	7.7
5	Blue stoned	do	3.25	11.0
7	do	do	3.25	11.5
9	do	do	3.5	11.25

Showed much checking during the burning.

Fusion test........................Small cones tested in gas-and-oil-burning furnaces deformed (f u s e d) between cones 32 and 33.

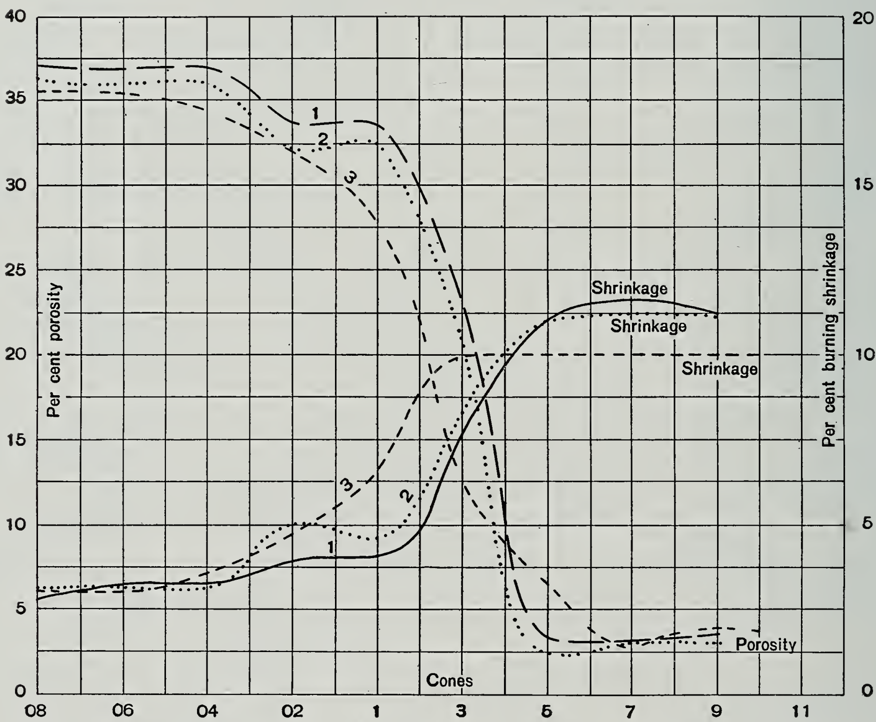

Fig. 6.—Graphic illustration of the laboratory tests of Samples 1, 2, and 3.

Sample 2

Color ....Bluish white
Plasticity ....Very good
Water content required...34.6%
Molding properties...................formed readily by hand and flowed easily through a die.

Tensile strength of dry briquets................123 pounds per square inch

Bonding strength....................................89 pounds per square inch
Slaking test..29 minutes

Screen test, residues left—

200 mesh	0.20%
100 mesh	0.09
80 mesh	0.11
40 mesh	0.02
20 mesh	0.00
Total residue	0.42%

Drying shrinkage..7.2%

Burning tests—

Cone	Color	Hardness	Porosity	Shrinkage
08	White	Scratched with knife	36.2%	3.0%
06	do	do	36.0	3.2
04	do	do	36.0	3.2
02	do	Steel hard	32.2	5.0
1	do	do	32.5	4.5
3	Light buff	do	21.2	8.2
5	Blue stoned	Vitreous	2.5	11.0
7	do	do	3.2	11.2
9	do	do	3.0	11.2

Fusion test................................Deforms between cones 33 and 34

Sample 3

Color ....Dark rose pink
Plasticity...Very good
Molding properties...................Soft, easily crushed; formed readily by hand.
Tensile strength of dry briquets..................95.5 pounds per square inch
Drying shrinkage..5.9%
Slaking test ....30 minutes

Screen test, residue left—

200 mesh	0.16%
100 mesh	0.14
60 mesh	0.10
40 mesh	0.00
Total residue	0.40%

Burning tests—

Cone	Color	Hardness	Porosity	Shrinkage
08	Pink	....	35.5%	3.0%
06	do	Steel hard	35.5	3.0
04	do	do	34.2	3.5
02	do	do	31.8	4.7
1	do	do	28.0	6.5
3	do	do	12.5	10.0
5	Faint pink	do	6.5	10.0
7	Grayish white	do	2.8	10.0
9	do	do	3.6	10.0
10	do	do	3.6	10.0

Fusion tests...............................Deforms between cones 33 and 34

These tests show similar pyrometric qualities as have already been reported for clay samples which were taken from pits in the Mountain Glen district many years ago.[1] (These early tests are given on page 175 of Bulletin 4, Illinois State Geological Survey). Chemical analyses of the old samples are tabulated below. Sample D 10 was taken at a depth greater than 50 feet; D 11, 40 to 44 feet in depth; D 12, 35 to 40 feet in depth; D 13 and D 14 were taken from the stock crib and represent the beds from the top of the deposit to a depth of 20 feet.

Sample	Moisture	Volatile	SiO_2	Fe_2O_3	Al_2O_3	TiO_2	Total per cent
D 10	1.25	9.90	43.90	1.76	40.79	2.40	100.00
D 11	0.97	15.37	48.30	1.02	31.14	3.20	100.00
D 12	0.86	8.64	56.55	1.23	29.97	2.75	100.00
D 13	0.90	9.05	47.95	1.23	37.86	3.01	100.00
D 14	0.87	10.61	52.65	0.97	33.98	2.92	100.00

From the mechanical and pyrometric tests made upon Samples 1 and 2, bluish-white clay, the following statement may be made concerning the uses and commercial qualities of the clay. We quote Mr. C. W. Parmelee of the Department of Ceramic Engineering, University of Illinois.

This material is a very fine-grained, plastic, strong, highly refractory clay well suited for use as a bond clay in the manufacture of high-grade refractories. Although its properties are not quite the same as those characterizing the European bond clays heretofore extensively imported for use in the manufacture of graphite crucibles, crucibles for brass meltings, and other purposes, yet this clay approaches so nearly as to warrant the belief that it may be used for these purposes.

The clay may be used also where a good bond clay is required, as, for example, in the manufacture of chemical stoneware. It also seems to be possible that further experiments may show that this clay may be substituted in certain products for ball clay, providing that the dark color developed by these clays at the higher temperatures is not objectionable.

As stated in the introduction, these clays are being satisfactorily used in place of the European clays in the manufacture of graphite crucibles and glass pots.

In regard to the commercial qualities of the pink clay, Sample 3, Mr. Parmelee says:

This clay is similar to clays 1 and 2 (bluish-white) in being a highly refractory bond clay and is suited to the purposes previously mentioned. It should be noted that this clay differs slighty with respect to the cone temperature at which it first attains its minimum porosity. Clays 1 and 2 show a minimum porosity attained at two cones lower than clay 3. This characteristic is likely to render clays 1 and 2 better suited to use for graphite crucibles.

[1] Purdy, Ross, and DeWolf, F. W., Illinois fire clays: Ill. State Geol. Survey Bull. 4, p. 175, 1907.

An unusual feature of this clay is the retention of a pink color (lilac at the higher temperatures) up to cone 5. This is most unusual, and a chemical analysis of the clay would be of much interest.

It is our opinion that the color of the clay does not affect its intrinsic value for the purposes mentioned and that any method of decolorizing the clay would be prohibitively expensive and of no real advantage.

Occurrence of Clays

The fire clays occur in bedded deposits, are underlain by sand, and overlain by sand, gravel, and in places an iron-cemented conglomerate.

In general, the covering is loess, the thickness of which varies from a few feet to 15 or more. Directly underlying the loess is a bed of water-worn gravels which are sub-angular to rounded, the size of the pebbles varying from a fraction of an inch to three inches in diameter. The thicknesses of the gravel beds vary from three inches to nearly two feet in the hillside deposits and up to eight feet in the deposits which are found in the lowland bordering the east branch of Clear Creek.

In typical exposures white and pale red, fine-grained, micaceous sands underlie the gravel bed and have a maximum thickness of about 20 feet. This deposit is thin or absent in places. Underlying the sand is the fire clay. In the large pit of the Illinois Kaolin Company the upper part of the fire clay is pink and the thickness 15 feet. Beneath the pink clay is a very thin bed of white clay at the west end of the pit, which thickens to 10 feet toward the center and east side. Bluish-white clay is below the white and in places has a workable thickness of 40 feet or more. In some pits as much as 17 feet of clay and lignite underlie the bluish-white commercial clay. Below this a white or red water-bearing sand is usually encountered.

Occasional sand lenses are found in the clay bodies and there are places where for a small thickness the clay may be sandy; the latter condition is especially true near the edge of a deposit. However, on the whole, the clays are quite free from sandy impurities. Pockets of refractory clay may be found in places within the sand beds that overlie the main clay bodies. This relation may be seen at the pit of the Illinois Kaolin Company. In a few places the upper part of the white or bluish-white clay has been stained by the action of surface waters, a light-brown to chocolate color probably being produced by organic acids, a pale red mottling probably being caused by iron solutions.

Lignite is present in small quantities in the bluish-white clay. The greatest amount is in the lower parts of the deposits and may make considerable quantities of the clay unfit for marketing. In one shaft of the French Clay Blending Company the drill showed the lower 17 feet of the deposit to be lignite and clay. Wherever small pieces of lignite are found, or where a piece may have lain, the clay is stained a dark chocolate color,

the amount of clay discolored depending upon the original size of the woody piece. These streaks are in all positions, vertical, inclined, and horizontal, a fact which strongly suggests that the original vegetable matter was washed into the depressions along with the clay. The present practice of discarding the lignite-stained clay should be discouraged. At the high heat to which this clay is subjected in most of its commercial usages, the organic stain should entirely disappear.

There are a few small prospects located well up on the hillsides. The relations existing at these deposits are partly obscure owing to the small amount of development work done. Some of the conditions of occurrence are similar to those found at the main deposits, but the clay is apparently of different quality. It is not very plastic and resembles more a pottery clay. The color is pink and white, and the texture is fine grained. Gravels overlie the deposits.

The basement of the deposits has never been determined by drilling, but the writer suggests that it is very probably limestone. Only one exposure of the wall rock was observed. This outcrop was about 300 feet southeast of the big pit of the Illinois Kaolin Company and was of Spergen limestone. Other outcrops of limestone may be seen near some of the other deposits, and it is the opinion of the writer that the clay deposits occupy depressions in a limestone area.

In at least one deposit the pink clay attains considerable thickness, a shaft on the Goodman property having passed through 93 feet. However. the surface elevation of the top of the pink clay of this deposit is very much higher than it is at the other deposits. Of special interest and a feature that may be of considerable importance in further prospecting is the elevation to which the bluish-white clay extends. If we consider only the deposits of tested high-grade fire clay, the highest elevation of the bluish-white and white varieties is about 470 to 475 feet above sea level. Other clays in the vicinity extend about 100 feet higher, but they are apparently of a different grade.

Origin of Clays

From a study of the geologic occurrence of the clay deposits, the sedimentary origin of the large deposits in which lignitic material is found is obvious. In the smaller deposits, wherever it is possible to study conditions, the occurrence of the clay as well as the underlying and overlying sand and gravel beds can be explained only by sedimentary deposition. However, the presence of large faults, and probably some smaller ones, suggests the possibility of finding some clay along one or more of the fault planes as an alteration product. The less-plastic clays found on the hills west of the mines may belong to this class.

The geologic processes that operated and the conditions that obtained during the accumulation of the sedimentary deposits found in and around

the clay mines may be stated in a short chronological history of events that must have taken place in the area.

The great Gulf embayment, which spread over much of the south-central part of the United States during Cretaceous-Tertiary time, reached as far north as the extreme southern end of Illinois. Deposits of sand and clay in Alexander, Pulaski, and Massac counties are evidence of this invasion of the sea. The finding of quite similar deposits just southwest of Mountain Glen would strongly suggest that an arm of this embayment had reached the northwestern part of Union County, very probably having followed the course of some stream valley west of the Devonian highlands of Union and Alexander counties. This arm of the sea probably followed valleys the position of which approximated the present Mississippi Valley and the smaller valley of Clear Creek.

The surface of the land over which this arm of the sea extended had depressions and higher places probably quite similar to the present surface of the land in this area. Deposits of sand and clay would, therefore, fill the low places first. The thickness of sand and clay in the deposits that are being worked is such as to suggest that here deposition took place in limestone sinks.

The first deposit was sand which was followed by bluish-white clay. Considerable vegetable matter was in the depressions and became mixed with the lower part of the clay producing the highly lignitic bluish-white clay that is found in the lower part of some of the deposits. During the deposition of the bluish-white clay more vegetable matter was washed into the depressions. Following the deposition of this clay, probably without a break, the white variety was deposited. There appears to have been a break in deposition following the white-clay stage for the thickness of the latter is variable. The waters in which the pink clay was deposited evidently reached a higher elevation than during the preceding stages, for at least one deep basin was filled which had not received any of the earlier clay sediments.

Following the main clay stages, red and white sand with some clay in pockets was deposited. Elevation of the land throughout the whole region at about this time caused the removal of fine sediment and the deposition of coarser material which we may tentatively classify as Lafayette.

To recapitulate, the fire-clay deposits are sedimentary in origin, the clay having been transported by water and deposited in depressions which existed in the old land surface.

Recommendations for Prospecting

If the origin as outlined is correct then we may expect to find clay bodies only where there were depressions in the land surface over which

the waters of these early times extended. The favorable places for deposition would be in small embayments where the movement of the water would be so slight as to allow the fine clay material held in suspension to settle, yet where fresh supplies could be continually introduced. Such conditions as these would probably not obtain along the main arm of the sea. Therefore, in the smaller reentrants we should expect to find clay deposits commensurate with the size of the surface depressions into which the clay could settle.

As has already been pointed out, there is a fault a short distance east of the mines which brings the sandstone, shale, and limestone formations of the Chester in contact with the soluble limestones of the lower Mississippian in which area the present known clay deposits occur. About half a mile west of the mines faulting has caused the Devonian shales and cherts to form the surface rocks. It is the writer's opinion that the large depressions into which the clay material could settle existed in the area of soluble limestone rocks between the two faults, these deep depressions being sink holes, and that probably only small depressions existed in the less soluble rocks outside the central fault block.

If these deductions are correct, the large clay deposits will be confined to a relatively small area, although somewhat larger than that already exploited, and the commercially valuable fire clays will probably not be found at a present elevation much greater than 480 feet above sea level. However, smaller deposits may be found outside this area, and prospecting for them should be encouraged, should the present demand for high-grade refractory clays continue.

The limiting of the present field as a result of geologic study in this small area should not be interpreted to mean that there are not good chances of finding large deposits in other parts of the region. Wherever an arm of the Gulf embayment may have reached an area underlain by a prevailingly soluble limestone, and where conditions were favorable for the deposition of clay material held in suspension, other large clay deposits may have formed.

DESCRIPTION OF CLAY PITS

Illinois Kaolin Company

The large pit, designated as "K" pit, of the Illinois Kaolin Company (fig. 7) is located in the SW. ¼ sec. 35, T. 11 S., R. 2 W., and is about a quarter of a mile west of Kaolin Station on the Mobile and Ohio Railroad. The pit has dimensions of approximately 150 by 200 feet and is about 80 feet deep at the west end. A section at the west end of the pit shows the following succession:

Section from "K" pit of Illinois Kaolin Company, SW. ¼ sec. 35, T. 11 S., R. 2 W.

Description of strata	Thickness Feet
Loess at top	..
Gravel bed	1
Sand, white, micaceous; in places stained pink	10
Sand, pink to dark purplish red, micaceous	10
Clay, pink to red, highly plastic	15
Clay, bluish white, highly plastic	15

At the southwest corner is a pocket of pink and white clay, slightly sandy, which occurs in the sand beds overlying the main clay body. At the east end of this pocket is an irregular iron-cemented conglomerate bed. On the north side of the pit is a small fault that runs approximately

Fig. 7.—Pit of Illinois Kaolin Company.

east and west. Along the fault plane is an iron seam and altered clay of a purple color. The south side is the downthrow, and the displacement is probably not more than 15 feet.

The clay is mined with two steam shovels and is hauled from the pit by a small engine. The cars containing the clay are run to a shed about 300 feet east of the pit, and unloaded on a platform where it is cleaned by hand. A switch from the railroad to the platform facilitates shipping. A large shed was erected in the fall of 1916 with a storage capacity of 5,000 tons. A drying plant is on the property but is not being used.

The company's property included three other pits none of which was being worked when the writer visited the district in October, 1916. About a quarter of a mile west of the big pit is an abandoned shaft 20 to 25 feet deep, known as "G" pit. It is claimed that there are 40 feet of

white clay with a little pink on top which is almost non-plastic. In this respect the clay differs greatly from the clays of the main deposit, which is about 100 feet lower in elevation.

About a sixth of a mile northwest of the big pit is a shaft known as "F" pit, from which pink and white, partly plastic clay was taken. The clay body is said to be 50 feet thick and to be underlain by red sand.

A little north of the big pit is the location of the earliest clay mining in the district, which was carried on by Dr. Goodman of Cobden. Pink, white, and bluish-white clay was mined from a shaft said to have been 75 feet in depth.

French Clay Blending Company

The property of the French Clay Blending Company is in the NW. ¼ sec. 35, T. 11 S., R. 2 W. All the mining on this property has been done in shafts. At the present time two shafts are being operated. They are 77 feet apart from end to end, and drifts are being run so as to connect the two. What is known as shaft No. 3 has a depth of 39 feet. Shaft No. 4 is 59 feet deep and passed through the following material:

Log of shaft No. 4 of French Clay Blending Company

Description of strata	Thickness *Feet*
Soil	2
Gravel	7
Clay, brown, highly plastic	14
Clay, bluish-white, highly plastic	36
Clay mixed with lignite	7
Sand, white, water bearing	..

A small thickness of mottled pink and white clay was encountered in the two abandoned shafts, extending below the gravel.

The two operating shafts are two-compartment shafts with inside dimensions 6 by 12 feet. They are well timbered from the top down to the lowest level. The drifts are also heavily timbered up to the working faces. The clay was hoisted in buckets by horse power at the time of the writer's examination, but a steam engine for hoisting is to be installed.

The company has constructed a gravel road between their mine and Mountain Glen, over which the clay is hauled to the railroad for shipment to their refining plant at Effingham, Illinois. There the clay is dried on shelves under which are steam pipes; then is handpicked, and crushed. The clay is marketed in sacks.

Frederick E. Bausch Mine

The Bausch clay mine is located approximately in the center of sec. 35, T. 11 S., R. 2 W., and just north of Kaolin Station. All mining is done by shafts and drifting to connect the shafts. There are three shafts,

two one-compartment and one two-compartment. At the time of examination there were three levels, the first at 20 feet, the second at 27 feet, and the third at 34 feet; lower levels were planned. The shafts and levels are heavily timbered. Hoisting is done by steam and windlass at present, but it is the owner's plan to electrify the mine in the near future. The clay is cleaned by hand in a shed before shipping.

The following is a section through the deposit:

Log of Bausch shaft, center sec. 35, T. 11 S., R. 2 W.

Description of strata	Thickness *Feet*
Alluvium	4
Gravel and alluvium	4
Clay, brown to cholocate color	3
Clay, bluish-white, highly plastic	23+

Goodman Pit

The pit owned by Dr. Goodman is located in the NW. ¼, sec. 2, T. 12 S., R. 2 W. All the clay taken from this deposit is of the pink variety. In spots it has a purple mottling. The clay is mined by a shaft which is immediately abandoned when the bottom of the deposit is reached. Mining is carried on only when there is a demand for a carload. Most of the clay is shipped to copper companies in the Lake Superior region, where it is used in lining retorts.

Log of Goodman shaft, NW. ¼ sec. 2, T. 12 S., R. 2 W.

Description of strata	Thickness *Feet*
Loess	10
Gravels	1
Sand, reddish brown, argillaceous	2
Clay, pink with purple spots, plastic, refractory	93
Sand, red, fine grained	15+

Abandoned Pits

There are a few abandoned pits and prospects in the area. The one which was probably the most important is in the NE. ¼ sec. 3, T. 12 S., R. 2 W. From appearances there evidently had been considerable mining at this point some years ago. At least two shafts were sunk and a platform 15 feet high and 30 by 30 feet built. The only clay seen on the ground was pink in color.

THE STRUCTURE OF THE LA SALLE ANTICLINE

By Gilbert H. Cady

OUTLINE

OUTLINE—Continued

ILLUSTRATIONS

TABLES

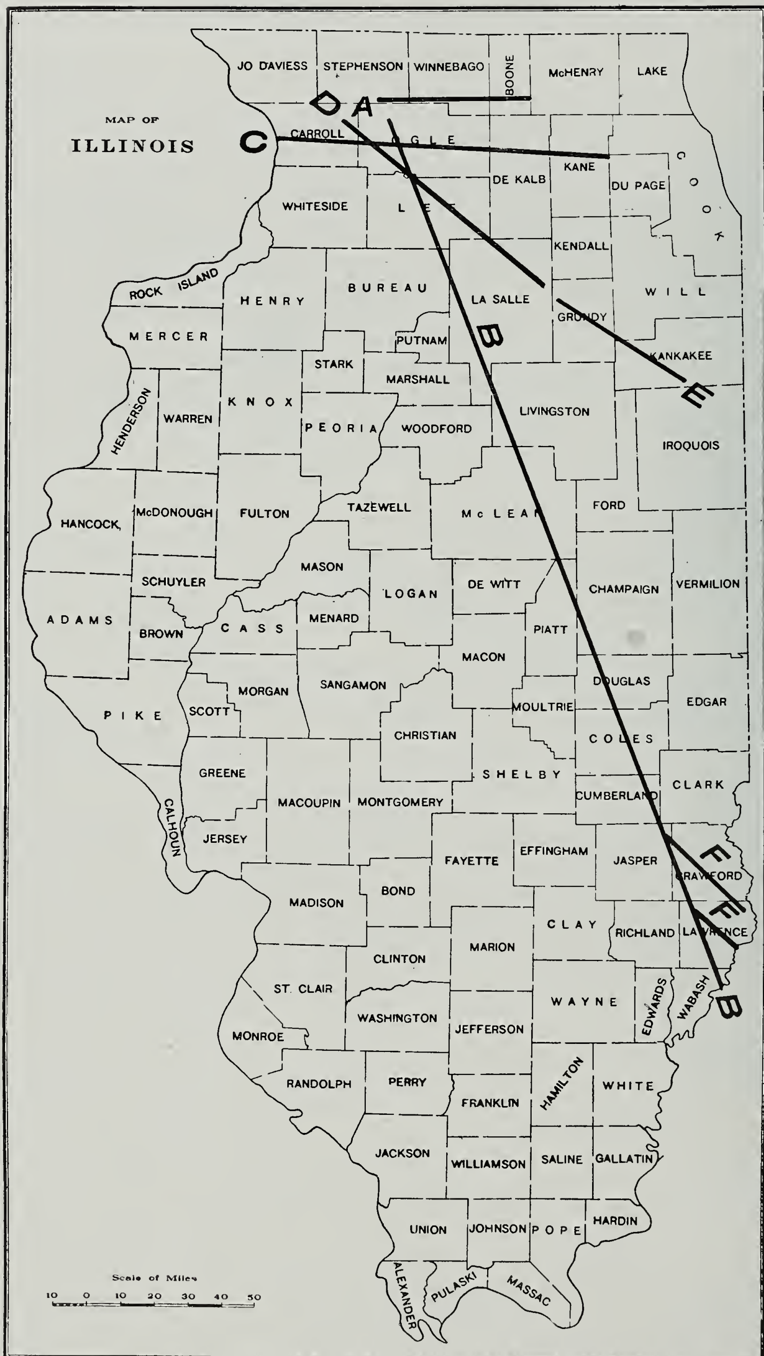

FIG. 8.—Sketch map of the structural elements in northern and eastern Illinois.

A. Stephenson-Ogle county line syncline.
B. LaSalle anticline
C. Savanna-Sabula anticline
D. Ogle, Lee, and LaSalle counties anticline
E. Morris-Kankakee anticline.
F. Anticlines and terraces diverging from the main anticline.

SYNOPSIS

The LaSalle anticline has been known as an asymmetrical fold probably extending in Illinois from Stephenson County on the north through Lawrence County on the southeast. The structure is well exposed along Illinois River near LaSalle, and from that town the deformation takes its name. The structural relationships are such that two periods of deformation are readily recognized, one between Galena and Pennsylvanian times and the other some time after the deposition of No. 2 coal in the LaSalle region.

The results of the present studies are to a large extent summarized in two structure maps, one (Pl. II) based on the altitude of the top of the St. Peter sandstone which shows the total amount of deformation since St. Peter time, and the other (Pl. VIII) based on the altitude of No. 2 coal which shows the amount of deformation since the deposition of that coal but which is applicable to a slightly different area than the first map. These maps show with as great detail as is practicable the position and form of the anticline and associated structures, and a comparison of the two gives an approximate idea of the character and amount of the structural unconformity between Pennsylvanian and pre-Pennsylvanian or possibly pre-Chester rocks.

The structural forms of special interest shown on the structure maps and described in the text consist of the following elements: (1) An asymmetrical anticline extending south from LaSalle into the oil fields of Crawford and Lawrence counties—the LaSalle anticline; (2) a synclinal trough to the east of the anticline, which becomes relatively deep in Vermilion County and which with the portion extending into Indiana, is the northern part of the Indiana coal basin; (3) a synclinal trough to the west of the anticline, which forms the larger and main portion of the Illinois coal basin. The anticline and adjacent synclines vary in strength because of the varying rates of southward pitch. In general where the crest of the anticline is high it parallels a place in the trough to the west that is correspondingly low, and where the crest pitches more steeply south the trough either rises or else pitches less steeply than the crest in the same direction. The southward pitch of the east trough seems to be fairly uniform as far as Vermilion County, but south of Vermilion County the rate of pitch decreases.

Additional elements of the structure may be cited: (4) A zone of inclined strata dipping into the coal basin is the continuation of the west

limb of the LaSalle anticline and can be traced in this State from LaSalle northwest toward the Mississippi near Savanna. East of the anticline the edge of the coal basin is less definitely marked, but seems to be represented across the fold by the steep pitch between LaSalle and Streator, and is possibly traceable northeast toward Sheridan. (5) A broad anticlinal uplift of rather indefinite extension continues from near Sheridan along Fox River northwest toward Elkhorn Creek basin in northwestern Ogle County, with a branch extending toward Savanna. This anticlinal structure will be called the Ogle, Lee, and LaSalle counties anticline. (6) The east side of this anticline is very irregular in contour, due to several minor anticlines and synclines directed toward the east from the larger fold.

Four of these minor transverse folds are described. The northernmost is a syncline which lies along the Stephenson and Ogle County line and seems to limit the main fold in that direction. This is the Stephenson-Ogle County-line syncline. At Oregon a well-marked anticline is apparently the extension of an anticline which crosses the Mississippi Valley at Savanna and at Sabula in Iowa—the Savanna-Sabula anticline. This deformation is abruptly terminated to the north near Oregon by a syncline, but the south limb has a gentle slope. The third minor structure is the Pawpaw-Aurora syncline, its position being indicated by its name. It has not been shown whether or not this syncline entirely crosses the main anticline as a well-defined feature. The slope of the strata in the south limb of this structure is steep, especially between Sheridan and Yorkville and between Somonauk and Sandwich. Finally, as a fourth structure there is the Morris-Kankakee anticline which practically amounts to a continuation of the larger Ogle, Lee, and LaSalle counties anticline toward the southeast.

The position of the various elements of structure as outlined above is shown graphically on the accompanying sketch map (figure 8).

In addition to the elements of structure shown by structure maps, others are also described. (7) A structural unconformity exists between Pennsylvanian and Mississippian strata in the southeastern Illinois oil fields, the older rocks pitching more steeply to the south and being more definitely folded across the anticline. Furthermore, (8) it appears that the strata are not steeply inclined eastward from the axis of the anticline, but that this gently inclined surface is interrupted by anticlines or terraces diverging from the axis of the LaSalle anticline and swinging off to the east. By these structures the east flank of the fold is broken into two or three steps the level of each of which is successively lower than the level of the step to the north.

Certain structural relationships between different formations, groups, series, and systems may be briefly summarized. (1) The struc-

ture of the "Lower Magnesian" limestone is not parallel to that of the St. Peter sandstone, but it is not evident that the deformation of the older strata is restricted to the later belt of folding. (2) A slight structural unconformity exists between the St. Peter sandstone and the Platteville dolomite. (3) Structural unconformity also exists between the Chester group and underlying strata and between the Chester group and the overlying Pennsylvanian strata. The fact of the unconformity below the Chester group is indicated by the rapid deepening of the Chester basin near its northern edge and by the non-parallelism of Chester and older Mississippian strata in Lawrence County. (4) There is apparently widespread structural unconformity below the Pennsylvanian system. (5) Within the Pennsylvanian system there is at least one and possibly two or more structural unconformities, and apparently the final movement along the anticline, at least toward the south, took place before the close of Pennsylvanian deposition.

The structural forms and relationships as presented in the preceding resumé may be interpreted from an historical point of view. The main result of such a study is to show the probability that the deformation along the anticline, except for slight and poorly defined movements at earlier times, took place between the close of the Lower Mississippian (pre-Chester time) and before the end of Pennsylvanian times, and that there were periodic movements during this interval.

The structures are also considered from the standpoint of earth dynamics. It is thought that the anticlinal structure and other structures described are contemporary with and possibly in part the result of the subsidence of the Chester and Pennsylvanian basins.

CHAPTER I—INTRODUCTION

Crossing Illinois from Stephenson County on the north to Lawrence County on the south is a persistent structural feature known as the La Salle anticline. By reason of the widespread covering of glacial drift over the hard rocks of the State, the surface configuration shows response to rock structure in only a few places, so that, as a surface feature, the anticline is not prominent. But were the drift entirely removed, as much of it has been in the valleys of the Rock and the Illinois, structures as interesting as those there displayed would be found generally along the folded area, and the crest or axis of the fold would, for much of its length, be the watershed between important river basins.

The La Salle anticline accounts for the variation in the age of the bed-rock across the northern part of the State. Erosion has beveled a fairly even surface across the uplifted strata, so that older and older beds are exposed toward the line of greatest uplift. The oldest rocks outcropping in the State, the "Lower Magnesian," are found outcropping here and there where the rocks have been uplifted, their occurrence indicating the trend of the deformation.

Formations of economic value become accessible because of this structure. Such are the "Lower Magnesian" limestone, a source of natural-cement rock; the St. Peter sandstone, from which is obtained large quantities of glass and foundry sand; and the Platteville limestone, used in the manufacture of Portland cement. The discovery of coal in Illinois was made along Illinois river on the east flank of the anticline. The economic importance of the deformation in southeastern Illinois in supplying structures favoring the accumulation of oil and gas needs no emphasis.

Aside from its economic bearing, the anticline has considerable general and academic interest. The very existence of this structural feature, in the midst of a region in which nearly flat-lying rocks prevail, is noteworthy. The relationship of the rock structure to the scenic picturesqueness of the Illinois and Rock river valleys where they cross the anticline is evident, and the successive changes in the rock strata outcropping in the bluffs of the Illinois between Ottawa and La Salle commonly excite the comment of the traveler. The La Salle region is visited yearly by classes from educational institutions and by others seeking illustrations of the simpler geologic principles.

Status of Investigations

That an asymmetrical anticline extends through Illinois from Stephenson County on the north to Lawrence County on the south has been believed for at least ten years. The inclination of the rocks in the La Salle region, where they are uncovered in the valley of the Illinois and along its tributaries, received mention in the literature more than fifty years ago, and the nearness of the city of La Salle to the exposures of inclined beds has given the deformation its more common name—the La Salle anticline. A broad uplift in Ogle and Lee counties, but one not producing conspicuous inclination of the rocks is especially evident in the vicinity of Grand Detour. The continuity of the uplift at Grand Detour with the anticline at La Salle was early suspected, and the name Grand Detour-La Salle anticline accordingly appears in the literature. The continuation of the uplift southeast from near La Salle into southern Livingston County was believed certain by the geologists of the Worthen Survey, and its probable continuation as far as Tuscola in Douglas County postulated by Worthen on the basis of a diamond-drill boring at that town. South of Tuscola the probable continuation of the fold was not definitely considered until the oil fields were developed in Clark, Crawford, and Lawrence counties in 1905 and 1906.

The existence of the anticline was accepted by the present Geological Survey as a rather vague condition of structure. Sufficient information has since been collected, however, to determine definitely its form and position for most of its length. The investigations in the oil fields have made it possible to trace the anticline through Clark, Crawford and Lawrence counties; the studies near La Salle have furnished much information concerning the details of the structure in that region; and enough field work has been done along the fold in Lee, Ogle, Carroll, and Stephenson counties to determine the general character of the deformation north of the coal basin. In the northeastern part of the State the lay of the rocks has been recently determined from detailed studies of the water-bearing strata by C. B. Anderson. From time to time, without respect to any definite investigations, the Survey has received the drilling records of wells located near the probable position of the axis of the anticline. With this sort of information, especially, it is possible to follow the structure from La Salle County through Livingston, McLean, Champaign, Douglas, and Coles counties to the southeastern Illinois oil field.

Statement of Purpose

The present report purposes to assemble the material relative to the form and position of the anticline that has been collected by the

present Survey, the primary endeavor being to map the position of the fold and to indicate its contour. Detailed observations of the structure in regions where the rocks outcrop will be presented as throwing light on the history of the deformation.

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CHAPTER II—HISTORICAL REVIEW

Resume of Literature up to 1908

A. H. Worthen[1] in 1866 described the approximate position of the axis of the anticline and its trend as follows:

"The most northerly [axis of disturbance] crosses the north line of the State in Stephenson County, and intersects Rock River at Grand de Tour and the Illinois at Split Rock between La Salle and Utica. This uplift brings the St. Peter sandstone to the surface on Rock River and the "Lower Magnesian" limestone (Lower Silurian) on the Illinois. Its general trend is from north-northwest to south-southeast, and its extent southward beyond the Illinois has not yet been determined. It elevates the coal measures to the surface in the vicinity of La Salle from a depth of from three to four hundred feet, this showing that the disturbance took place at a period subsequent to the deposition of the coal formation."

Worthen failed to describe the structural unconformity which is one of the most conspicuous features of the anticline in the LaSalle region, deformation plainly having taken place both before and after the deposition of the "Coal Measures". H. C. Freeman[2] (1868) contributed the following information in regard to the evidence of two periods of folding:

"West of the axis the Coal Measures, where resting on the Trenton at the outcrop, are inclined at an angle of about ten degrees, the dip of the Trenton being forty degrees. The Coal Measures extend over and rest unconformably on the St. Peter's also, at about the same angle. The Trenton and St. Peter's are everywhere conformable to, and appear to be the same with, the Calciferous.

"The good exposures of Trenton and St. Peters, from Deer Park northward, on the west side of the axis, give a dip of forty degrees to the southwest. Southward from Deer Park the dip becomes less, being about six degrees at Lowell, with the Coal Measures still unconformable at a less angle. * * *

"North of the Illinois River, east of the axis, and in the Illinois bluffs on the south side, the Coal Measures resting on the St. Peter's sandstone are conformable to it. Farther south there seems to be an increasing dip in a southeast direction of the sandstone, or a less dip of the Coal Measures, and the Trenton comes in between. This may be seen in Covel Creek near its mouth."

Freeman's account of the unconformity at Split Rock and Deer Park and the structural relation of the "Coal Measures" and older rocks west of the axis of the anticline is essentially correct and so far as it goes can be accepted today. The relationship of the "Coal Measures" and St. Peter sandstone east of the axis is everywhere apparently one of unconformity and not conformity as Freeman states. Freeman also in

[1] Worthen, A. H., Geol. Survey of Illinois, vol. 1, p. 5, 1866.

[2] Freeman, H. C., La Salle County: Geological Survey of Illinois, vol. 3, p. 261, 1868.

the same pages from which the preceding quotations are taken, describes with considerable detail the course of the "anticlinal axis" across LaSalle County.

Seven years later (1875) the same writer[1] described the continuation of the "anticlinal" axis into Livingston County as follows:

"The great anticlinal axis which crosses the Illinois River near Utica, in La Salle County, and which is very clearly defined in the north bluff of the Illinois Valley, having its central line two miles west of Utica and a direction of south 33 degrees east, extends through Livingston County, its central line lying a little east of the Vermilion River."

In 1873 the Hon. James Shaw[2] contributed the volume of the Illinois reports which concerns the geology of northwestern Illinois, including Ogle, Lee, and Stephenson counties. In the chapter on Lee County he says:

"The St. Peter's sandstone on Rock River, as will be seen by a reference to my report upon the geology of Ogle County, is chiefly developed in the latter county. For a distance of about fourteen miles above Oregon city and terminating a short distance below the mouth of Pine Creek, it is a very marked feature of the Rock River bluffs. The outcrop extends back but a short distance from the bluffs. In some of the ravines and intersecting streams it can be traced for one, two, or three miles. On the east, north, and west of these sandstone bluffs, the formation terminates abruptly, sinks out of sight rapidly, and seems like an abrupt anticlinal axis pushed boldly up into the air. On these sides the overlying formations are piled as it were against the side of the sandstone uplift. But on the south side it sinks away more gradually, and doubtless is the underlying rock for most of the distance in a southeast direction to the great upheaval at Deer Park and Starved Rock, on the Illinois River. A line drawn from the mouth of Franklin Creek up that stream, thence on a southeast course to the southeast corner of Lee County, and thence to the Illinois River through La Salle County, for the most or all of that distance passes over this deposit. A line from Oregon city to the same point. or lines from intermediate points on Rock River to the same point would pass over formations almost identical. From the uplift on Rock River to that on the Illinois River, there is probably a low axis of elevation somewhere in the section of the county bounded by the above imaginary lines."

The preceding account of the structure in Lee County merits recognition mainly because of the suggested correlation of the Lee-Ogle counties uplift with the anticline described by Worthen and Freemann at La Salle. The details of the structure in Lee and Ogle counties are unscientifically described, and it is evident from recent investigations in the region that many significant geological features were overlooked.

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[1] Freeman, H. C., Geology of Livingston County: Geol. Survey of Illinois, vol. 6, p. 235, 1875.

[2] Shaw, James, Geology of Lee County: Geol. Survey of Illinois, vol. 5, p. 124-139, 1873 (p. 127).

The presence and general position and extension of the anticline had apparently been recognized by 1882 for in that year T. C. Chamberlin[1] presented a map of Wisconsin and parts of adjoining states, showing the main flexure axes and dips. On this map is shown a main-central north and south axis beginning just north of Pecatonica River between Freeport and Rockford, and continuing thence northward to the Lake Superior heights. The La Salle-Grand Detour axis is indicated as passing near La Salle and Grand Detour and as possibly continuing in a northwest direction along the west watershed of the Pecatonica basin to the central part of the southwestern Wisconsin lead and zinc region. Another axis is shown as possibly running east-northeast from Savanna toward the Pecatonica and Rock rivers and crossing the axis of the La Salle anticline in the vicinity of Polo, Ogle County, Illinois.

The next important contribution to the knowledge of the anticline is in volume VIII of the Geological Survey of Illinois[2] published in 1890. In the chapter on economic geology Worthen describes the core from a diamond-drill boring at Tuscola in Douglas County, and writes as follows:

"The oblique fracture of the core taken from this boring showed that the limestones passed through, dip at an angle of about 20 degrees, which would give an exaggerated thickness to the beds as reported, and shows that this boring is on, or very near the center of the great anticlinal axis, which crosses northern Illinois diagonally through the counties of Ogle and La Salle, but is hidden in its southeastern extension by the superincumbent deposits of drift material.

"There is probably a considerable area along the line of the above-mentioned axis extending through the counties of Livingston, Ford, Champaign and Douglas, that is colored as coal measures on the map, where no valuable deposits of coal will be found, such deposits having been removed by erosion if they formerly existed over the axis as seems probable, but the boundaries and extent of this barren area can only be determined by the drill, or artificial excavations, as there are no natural outcrops that will help to define its extent. * * * How far south this axis extends is a point as yet undetermined by the drill or the more expensive method of shafting. If it extends to the Wabash River it would cross that stream in the vicinity of Vincennes."

Until the investigations by the present Survey in the newly developed southeastern oil field in 1905 the preceding statements by Worthen represented the latest knowledge relative to the continuation of the fold to the southeast. Meanwhile O. H. Hershey,[3] an independent investigator, worked out some of the structural features of the northern part of the

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[1] Chamberlin, T. C., Geology of Wisconsin, vol. 4, Pl. VIII, 1882.

[2] Worthen, A. H., Economical Geology: Geol. Survey of Illinois, vol. 8, p. 25, 1890.

[3] Hershey, Oscar H., The Elkhorn Creek area of St. Peter sandstone in northwestern Illinois: Amer. Geol. vol. 14, p. 176, 1894.

State, north of the Grand Detour, and discovered the area of St. Peter sandstone and "Lower Magnesian" limestone in the Elkhorn Creek basin. Of the structure in this area he writes in 1894:

"The area whose geology is under discussion is crossed by three anticlinal axes. The main axis trends from northwest to southeast and is a continuation of the Grand de Tour-La Salle anticlinal, which is the chief axis of northern Illinois. This anticline in the Elk Horn district is not very prominent, the strata dipping in both directions from the crest at a rate not exceeding 30 feet per mile. This alone could not have brought the St. Peter sandstone to light; but it is the intersection of this with two east and west anticlinals which has so elevated the formation that stream erosion has laid it bare. These two secondary axes are so close together that the synclinal trough between is almost imperceptible. It is rather to be described as a flat-topped uplift from one to two miles wide, with a slight axis or ridge at either side of it. But from the fact that these two bordering ridges diverge and become more easily distinguishable to the west, I prefer to consider them as two anticlines. They sweep across the district in slightly curved lines, trending in a general east and west direction, and concave to the north. On a line directly south from the city of Freeport, the curvature is rather more decided than farther east or west, the axis there turning from a slightly south of east to a slightly north of east direction. It has been observed that all deformations of this portion of Illinois which come in by gently curved lines from Iowa turn rather abruptly toward the east-northeast on or near this same north and south line. From this fact, and because there was sometimes an island and always an ascent to an elevated part of the sea bottom on the site of the present Elk Horn valley, it is inferred that this line occupies the position of the crest of a southern prolongation of the ancient area of uplift which has been frequently denominated the "Isle of Wisconsin". This, in the subsequent reelevation and corrugation of the territory, would determine the position of the most southern point of the various anticlinals which Chamberlin, McGee, and other geologists have shown to sweep around the Isle of Wisconsin in approximately concentric courses."

Hershey's description of the Elkhorn Creek area was followed the next year by a description of a cross section through the La Salle region from Rock Island to the Indiana State line by Professor J. A. Udden.[1] Udden had access to numerous records of deep wells drilled since the earlier investigations. With the help of these he was able to show that whereas the Pennsylvanian rocks rest upon St. Peter sandstone east of the anticline, they lie upon Niagaran or possibly Devonian rocks west of the fold. Concerning the structural features of the anticline he says:[2]

"These are of the simplest kind and may be regarded as typical of the structure found in the upper Mississippi Valley. We see two blocks of horizontal or only very slightly inclined strata separated by a monoclinal fold.

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[1] Udden, J. A., A geological cross section across the northern part of Illinois: Rept. of the Ill. Board of World's Fair Commissioners, p. 122, 1893.

[2] Idem, p. 144.

The downthrow and the trough limb is on the west, while the upthrow and the arch limb is on the east. The total displacement of the Silurian strata amounts to 1,575 feet, while the Carboniferous beds are only displaced about 625 feet. The trend of the axis of disturbance is considerably west of north, the strike of the outcrops of the upturned coal measures being about N. 30° W. The average dip in the displacement at La Salle is about 22 degrees for the Silurian rocks and about 8 degrees for the coal measures. The block of strata west of the monocline is nearly horizontal in an east to west direction from Rock Island to Annawan and from Princeton to La Salle, but between Annawan and Princeton there is a dip to the east of about 25 feet to the mile, or there is a concealed displacement of that extent between these two places. This dip may partly be accounted for by the dip to the south which is along the whole section. The block of strata on the east of the monocline has a nearly uniform dip to the east of about 12 feet to the mile."

In 1896 and again in 1899 Leverett[1] made important contributions to the geology of the State and incidentally to the knowledge of the La Salle anticline. In the earlier report Leverett summarizes the information regarding the anticline to date and presents on Plate CXIII a hypsographic map of the St. Peter sandstone of Illinois and western Indiana. On this map areas where the sandstone is respectively above sea level, within 500 feet below sea level, and more than 500 below sea level are shown by colors. He also presents a cross section[2] of the State from Rock Island to Joliet similar to the one presented by Udden. The map and cross section are reproduced in the Illinois Glacial Lobe,[3] published in 1899.

Following the organization of the present State Geological Survey there was prepared by Professor Weller[4] a brief summary of the geology of the State to accompany a geologic map. This summary includes a statement of the information available concerning the anticline but does not relate to new investigations except in the southeastern Illinois oil region. On the geologic map the upper and lower "Coal Measures" are distinguished and the "northeastern border of the area colored as Upper Coal Measures * * * * * is drawn along the supposed southeastward extension of the anticlinal axis which has elevated the older Ordovician formations, the Lower Magnesian limestone, and the St. Peter sandstone in Ogle, Lee, and La Salle counties. In the present map," to continue to quote from Weller, "this line is drawn farther to the west in its southern

[1] Leverettt, Frank, Water resources of Illinois: U. S. Geol. Survey 17th Ann. Rept. pt. 2, p. 790, 1896.

[2] Idem, p. 792.

[3] Leverett, Frank, Illinois Glacial Lobe; U. S. Geol. Survey Mon. 38, p. 554, and Pl. XXIII, 1899.

[4] Weller, Stuart. The geological map of Illinois: Illinois State Geol. Survey Bull. 1, 1906.

extension than in the original Worthen map. This change was made on account of data secured at Tuscola and near Urbana, made since the publication of that map,[1] and because of data more recently obtained from the development of the oil fields southeast of Charleston which seems to be associated with the extension of the La Salle anticline. Nearly the entire area through which this line is drawn is so deeply covered with drift that no rock outcrops are anywhere exposed, and the distribution of the underlying formation can only be determined through the records of deep-well borings which are all too few."[2]

The same year a map showing the position of the La Salle anticline was published by Professor Weller in a bulletin by W. S. Blatchley[3] on the Petroleum Industry of Southeastern Illinois.

In 1908 Bain[4] discusses the deformation as follows:

"The best known and probably most important [anticlinal] is the La Salle anticline. This is represented in Ashley's sections D-D and E-E.[5] In the former it is incorrectly shown as due to faulting. The major deformation at La Salle is by folding and the difference in position of the coal beds on opposite sides of the line of deformation is complicated by unconformity. Faulting if present is a minor phenomenon. In section E-E Ashley correctly indicates a probable anticlinal structure a short distance east of Charleston. This same structure was indicated by Weller, and its important relation to the oil pools pointed out in advance of the development in Lawrence County, and when in fact, very little oil had yet been found in Crawford County. * * *

"If the La Salle anticline be projected on any good map, it will be found to run through not only the present producing pools in Illinois but the Princeton field in Indiana. The fact that in southeastern Illinois the general structure of the field is anticlinal is abundantly proven, both by study of rock outcrops and drill records."

The details of the structure in the Clark and Cumberland county fields are described to some extent for the first time by Bain[6] in the article from which the previous quotation is taken, as follows:

"It remains true that within the general limits of the La Salle anticline there are evidently modifying conditions which determine the productivity or non-productivity of individual areas. The distribution of the gas and oil in

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[1] Geol. Survey of Illinois vol. 8, p. 25.

[2] Weller, Stuart, The geological map of Illinois: Ill. State Geol. Survey Bull. 1, p. 22, 1906.

[3] Blatchley, W. S., The petroleum industry of southeastern Illinois: Ill. State Geol. Survey Bull. 2, Pl. I, p. 22, 1906.

[4] Bain, H. Foster, Geology of Illinois petroleum fields: Economic Geology, vol. 3, p. 486, 1908.

[5] Ashley, G. H., The eastern interior coal field: U. S. Geol. Survey 22d Ann. Rept., pt. 3, Pl. XVIII.

[6] Idem, p. 487.

individual pools seems to point to something more than differences in porosity of the beds, though that is undoubtedly important here as elsewhere. Along the south line of Westfield Township, level lines have been run to a number of wells, and the oil sand has been correlated. This work shows the presence of an arch four miles wide, with its crest 100 feet above the lowest explored portion of the limbs. Six miles south, a similar line of wells shows an arch 129 feet high with an explored width of two miles. Across the Siggins pool to the west a similar section shows a 68-foot arch, four miles wide. It is interesting to note that the Siggins pool shows an arch parallel to the main one, and that the barren area between the two pools corresponds to a depressed or possibly synclinal area between".

Field Observations Since 1908

By 1908 the general position and extension of the anticline within Illinois had been pointed out. Subsequent investigations have involved more detailed study of portions of the fold such as was afforded (1) by detailed geological investigations in the field, (2) by the great number of drill holes located in Lawrence and Crawford counties after the discovery of the oil pools, and (3) by the constantly increasing number of wildcat drillings adjacent to the anticline and additional deep wells for water. The investigations concerning the structure in Crawford and Lawrence counties in the southeastern part of the State were made between 1908 and 1913 by R. S. Blatchley, and the results of these investigations appear in various bulletins, magazines, and journals between these dates. More recently the area of the Birds and Vincennes and Sumner and Hardinville quadrangles located in the Lawrence and Crawford county field has been restudied by Blatchley, Savage, and Rich. [1] The Allendale field which probably has structural relationship with the La Salle anticline was described in 1915 by J. L. Rich.[2]

Geological work in the northern part of the State along the anticline has been done almost entirely by the writer in connection with investigations of cement resources of the State in 1907,[3] the mapping of the geology of the La Salle quadrangle in 1912, in investigations of the coal re-

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[1] Rich, J. L., Oil and gas in the Birds quadrangle: Ill. State Geol. Survey Bull. 33, p. 105, 1916. Also, Oil and gas in the Vincennes quadrangle: Ill. State Geol. Survey Bull. 33, p. 147, 1916.

Savage, T. E., and Blatchley R. S., Description of the Sumner and Vincennes quadrangles: Unpublished manuscript, Ill. State Geol. Survey files, 1914.

Savage, T. E., Description of Hardinville quadrangle: Unpublished manuscript, Ill. State Geol. Survey files, 1914.

[2] Rich, J. L., The Allendale oil field: Ill. State Geol. Survey Bull. 31, pp. 59-67, 1915.

[3] Cady, G. H., Cement making materials in the vicinity of La Salle, Illinois: Ill. State Geol. Survey Bull. 8, pp. 127-134, 1908.

sources of the Longwall district in 1914, [1] in special investigations in Lee, Ogle, and Stephenson counties in 1915, and in mapping the geology of the Ottawa quadrangle in 1916.

During the years following 1908 Professor Udden reported on several wells located near to the axis of the anticline as indicated by Weller. The records of these wells have been published by the State Geological Survey.[2] Drill samples of other wells have been studied by Professor T. E. Savage and by other members of the Survey.

More recently, principally in 1914 and 1915, Mr. C. B. Anderson carried on elaborate investigations of the water resources of northeastern Illinois and added materially to the knowledge of the structure and stratigraphy and areal geology of that part of the State. Liberal use has been made of records and information collected by Mr. Anderson.

Paleontologic and stratigraphic investigations of strata involved in the fold have been made from time to time by Professor T. E. Savage, especially as concerns the Richmond formations and the rocks of the Alexandrian series. The results of investigations of the Richmond formations have not been fully determined, but enough has been done to convince Professor Savage of the existence of a faunal barrier during Richmond times at approximately the position of the La Salle anticline.[3] In a recent paper on the Alexandrian series he refers to a certain group of rocks as being "on the east side of the La Salle anticline."[4]

Stratigraphers, paleontologists, and paleogeographers, except for Savage, have failed in general to accord the anticline its merited attention. This is probably because of the lack of actual description of the structure except for almost casual references in the literature, and hence of a lack of appreciation of its possible significance.

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[1] Cady, G. H., Coal resources of District I (Longwall): Ill. Coal Mining Investigations Bull. 10, 1915.

[2] Udden, J. A., Some deep borings in Illinois: Ill. State Geol. Survey Bull. 24, 1914.

[3] Oral communication.

[4] Savage, T. E., Alexandrian rocks of northeastern Illinois and eastern Wisconsin, Bull. Geol. Soc. Amer. vol. 27, p. 305, 1916.

CHAPTER III—DESCRIPTION OF THE STRUCTURE OF STRATA OLDER THAN PENNSYLVANIAN

General Statement

The description of the structure of the La Salle anticline will be considered under two heads, namely, the structure of rocks older than Pennsylvanian and the structure of Pennsylvanian rocks. This division of the subject seems advisable because of the lack of Pennsylvanian strata over the northern part of the State and because of the structural unconformity between Pennsylvanian strata and earlier rocks within the area in which the Pennsylvanian rocks are present, signifying a deformation previous to Pennsylvanian time.

Stratigraphy

In the following description of the structure of the pre-Pennsylvanian rocks a general knowledge on the part of the reader of the details of the stratigraphy of the State such as may be gained by a study of the geologic map furnished by the State Geological Survey is assumed. An understanding of the structure requires mainly an appreciation of the relationship of the following strata or series of strata. At the top are the Pennsylvanian coal measures consisting of shales and sandstones with minor amounts of limestone and coal; below the Pennsylvanian, where not eroded or absent are the Upper Mississippian or Chester shales, sandstones, and limestones, followed below by the Lower Mississippian limestones and calcareous shales, the Devonian black shale and limestone, the Niagaran dolomite, the Ordovician shales and limestone of Richmond age, dolomite and limestone of Galena-Platteville or Kimmswick-Plattin age and sandstone of St. Peter age. The St. Peter sandstone is commonly underlain by a heavy dolomite or dolomite and sandstone—the "Lower Magnesian"—which rests upon a series of sandstone, sandy shales, and dolomite that is commonly but incorrectly called Potsdam sandstone. The general relationship of these various members of the geologic section in Illinois is shown on the columnar sections and structure cross-sections that accompany the geologic map of the State. The stratigraphic relations and distribution of these various members of the Illinois section cannot be discussed here; it is sufficient for the purposes of this report to state that the main divisions especially those below the Silurian and above the "Lower Magnesian" are recognizable over large areas. Thicknesses seem to be persistent and characteristic, and lithologic variations are lack-

ing or are of minor importance, so that the identification of the lower members of the section is not difficult lengthwise of the anticline.

Selection of a Structure Datum

Of the formations most readily recognizable the St. Peter sandstone is especially characteristic. It is essentially the only sandstone below the Chester or Upper Mississippian and lies between two massive dolomite formations. Furthermore, its physical characteristics are conspicuous, the grains being composed of colorless quartz, each grain being well rounded and all grains of a fairly uniform size. From observations in areas of outcrop, it is believed that the surface of the sandstone was essentially level when the succeeding dolomite was laid upon it, or that if irregularities did exist the relief did not exceed 40 to 50 feet. Accordingly deformations which have affected strata along the anticline can be measured by reference to the surface of the sandstone as a datum plane.

Structure as Determined by the Areal Geology

In the review of the literature up to 1908 the general position and character of the fold has been indicated. Subsequent description concerns certain features and relationships not described by earlier investigators, either because the information was not at hand or through failure to interpret correctly or to observe phenomena.

One of the readiest means of determining the position of the axis of the La Salle anticline is by tracing the outcrops of the various formations and mapping the geologic boundaries. Comparison of the various geologic maps of the State issued since 1906 will give some idea of the progress made in a correct delineation of the structural features of the State. Inspection of the latest geologic map [1] will immediately indicate the probability that an axis of deformation passes southward through the central part of the northern portion of the State. The parallelism of the geologic boundaries is significant of anticlinal or synclinal structure. As the oldest rocks are arranged more or less along a line in the central part of the area, the structure must accordingly be anticlinal.

The distribution of the inliers of "Lower Magnesian" limestone is indicative of the trend of the fold. The early geologists described areas of this formation in the vicinity of La Salle, along Elkhorn Creek, and possible areas along Rock River near Oregon. Lines connecting these areas, especially one from Elkhorn Creek to La Salle, were thought to represent the axes of greatest uplift. The areas where the surface rocks are St. Peter sandstone or "Lower Magnesian" limestone are more or less isolated and were, except for the Elkhorn Creek area, poorly mapped by the

[1] Edition of 1917.

early investigators. Later mapping, mostly by the writer, in La Salle, Lee, and Ogle counties has resulted in a more detailed delineation of the areas underlain by these formations and in a correspondingly better idea of the structure. There follows a description of the distribution of the "Lower Magnesian" limestone according to the most recent information.

In the La Salle region areas of this formation have been mapped along Illinois River and Pecumsaugan Creek and along Little Vermilion River and its tributary, Tomahawk Creek. In Lee County a large area previously mapped as Platteville-Galena dolomite has been identified near Franklin Grove along Franklin Creek. A small area of New Richmond sandstone underlying the upper dolomitic member of the "Lower Magnesian" formation is also exposed along this creek. In Ogle County several detached areas have been discovered on the east side of Rock River along a nearly straight line joining the middle of the south line of T. 22 N., R. 10 E., and the northwest corner of T. 23 N., R. 10 E., hence running slightly west of north (see Plate I). Other areas have been found along this same line west of the Rock and as far north as the middle of the north line of sec. 6, T. 23 N., R. 10 E., about two and one-half miles west of Oregon. The numerous areas of "Lower Magnesian" along this line are possibly indicative of the existence of an axis of uplift in the same position, or possibly only of a linear arrangement of areas of the pre-St. Peter surface having high relief and therefore not deeply buried beneath the sandstone. It is possible furthermore that both of these conditions obtain.

Certain small inliers of St. Peter sandstone also indicate the position and extent of uplift along the deformation. An outcrop of St. Peter sandstone in the valley of Leaf River near the town of that name extends for about a mile nearly north-northwest from near the center of the SE. ¼ sec. 25, T. 25 N., R. 9 E., to the center of the SE. ¼ SE. ¼, sec. 23 of the same township. This is the most northerly occurrence of the St. Peter sandstone known in the State [1] and lies along the alignment of "Lower Magnesian" outcrops near Oregon described in the preceding paragraph. Southeast of Franklin Grove one mile north and three-quarters of a mile east of Lee Center a small area of St. Peter sandstone in contact with Platteville dolomite was observed at the center of the SW. ¼ sec. 33, T. 21 N., R. 11 E. (see Plate I.) This area of St. Peter sandstone lies on the projection of the line joining the Elkhorn Creek area of uplift and the position of maximum uplift along Franklin Creek, but lies

[1] Since the above was written Prof. R. D. Salisbury reports the discovery of an area of St. Peter sandstone along Sugar Creek in Winnebago County, about 1 mile south of the State line.

east of the projection of the line connecting the areas of exposure of the "Lower Magnesian" formation north of Franklin Grove and the Leaf River area of St. Peter sandstone. The southward projection of neither of the lines will pass through the La Salle County areas of "Lower Magnesian".

The exposures of St. Peter and "Lower Magnesian" formations in northern Illinois probably are located at the positions of greatest uplift. Attempts to line up the areas along fixed directions for long distances do not, however, seem to be practicable, the uplift being broader and probably having less unity than such an alignment calls for. Furthermore the exposures are to a certain extent, though not always, dependent upon depth of erosion, the older rocks being exposed in the valleys; hence areas that may be structurally elevated but not deeply eroded do not show the lower rocks as surface formations. It seems apparent, therefore, from the areal geology of the St. Peter and "Lower Magnesian" formations that the structure in northern Illinois is not determined by elevation along a well defined anticlinal axis which is persistent in direction.

The areal geology of northern Illinois also indicates the existence of deformations transverse to the axis of the La Salle anticline, the structures produced by which are as conspicuous as those effected by the major deformation. An area of St. Peter sandstone elongated in an east-west direction lies across Rock River at Oregon. That a transverse axis of elevation crosses the State at about this latitude is also shown by the area of St. Peter sandstone and "Lower Magnesian" limestone along Elkhorn Creek and by the areas of Maquoketa shale to the west at Savanna and to the east along Fox River at Batavia.

Structure as Observed in Outcrop

The larger features of the deformation in northern Illinois have been determined by studying the areal geology; from the exposures it is possible to determine the form of the structure and the structural relationships of the strata involved. The ensuing paragraphs do not attempt to describe fully the structure of the different formations, giving in detail facts of distribution and altitude that would commonly be shown graphically on a topographic base. Topographic maps of La Salle, Ottawa, and Dixon quadrangles are available. Detailed geologic mapping of the La Salle and Ottawa quadrangles has been completed and the data for all three will be published within a reasonable time, so that description in great detail of the areal distribution and structure is thought to be impracticable for this discussion, the main purpose of which is to indicate the general character and form of the deformation.

"LOWER MAGNESIAN" LIMESTONE

LA SALLE REGION

In the La Salle region the line of maximum elevation along the anticline lies to the east of the axis of maximum deformation where the rocks are most steeply inclined; the "Lower Magnesian" limestone is exposed along the line of maximum elevation but not in the belt of steeply inclined rocks. Accordingly the outcropping rocks of this formation are only slightly warped and it is possibly significant that the deformations have no constant direction of alignment.

The detailed structure of the "Lower Magnesian" as observed along Illinois Valley and Pecumsaugan Creek is indicated in figure 9. It will be noted that there is considerable variation in the direction and amount of dip, the structure being characterized by numerous small anticlines and synclines. In the north bluff of the Illinois valley the formation attains its greatest altitude near the mouth of Pecumsaugan Creek where one of the cement beds formerly mined for natural cement is about 20 to 25 feet above the railroad track. About one mile east the same bed is about 4 feet above the railroad track; and by reason of a monoclinal fold half a mile farther east, it is 20 feet lower bringing it beneath the valley floor in the vicinity of Utica.

There is some evidence that the deformation of the "Lower Magnesian" took place before the deposition of the St. Peter sandstone. The structure of the older formation as observed in outcrop is apparently dissimilar to that of the younger rocks especially as concerns the alignment of the structure, the axes of the small folds bearing to the northeast more commonly than to the northwest. A close comparison of the structure of the "Lower Magnesian" with that of the younger rocks is not possible as the St. Peter sandstone is eroded in places where the "Lower Magnesian" limestone is typically exposed. Because the two formations fail to appear in the same cliff, it is not possible to say with certainty that the structures affecting the older rocks do not pass up into the sandstone. Along the south bluff of the river where the limestone is unexposed, except very locally, it probably lies near the base of the sandstone bluff even as far east as Starved Rock, where the "Lower Magnesian" forms the bed of the river. Accordingly, if the small flexures of the "Lower Magnesian" were formed subsequent to the deposition of the sandstone, there should be some evidence of structures along this sandstone bluff, provided, of course, that the movements were not confined entirely to the areas now exposed. It should be stated that small irregularities in the position of the sandstone have been noticed along Illinois river between Buffalo Rock and Ottawa, in connection with the small Covel Creek syn-

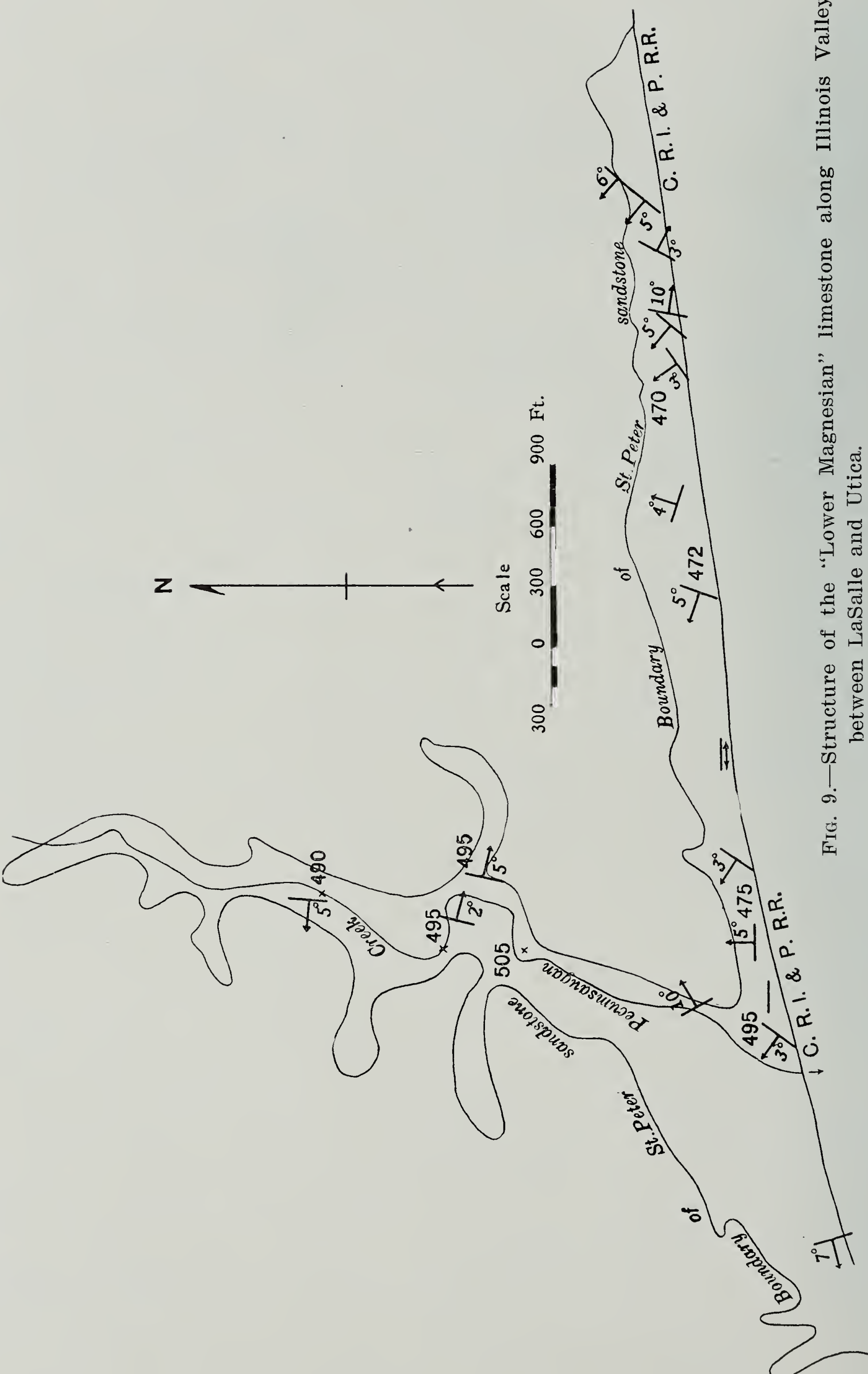

FIG. 9.—Structure of the "Lower Magnesian" limestone along Illinois Valley between LaSalle and Utica.

cline, but not elsewhere. The general absence from the sandstone of such flexures, with their presence in the limestone in this and other regions, is suggestive that the "Lower Magnesian" limestone was slightly folded prior to the deposition of the St. Peter sandstone.

LEE AND OGLE COUNTIES

In general the "Lower Magnesian" in Lee and Ogle counties is about horizontal, but the exposures are of insufficient extent and the details of the stratigraphy too little known to determine the regional structure

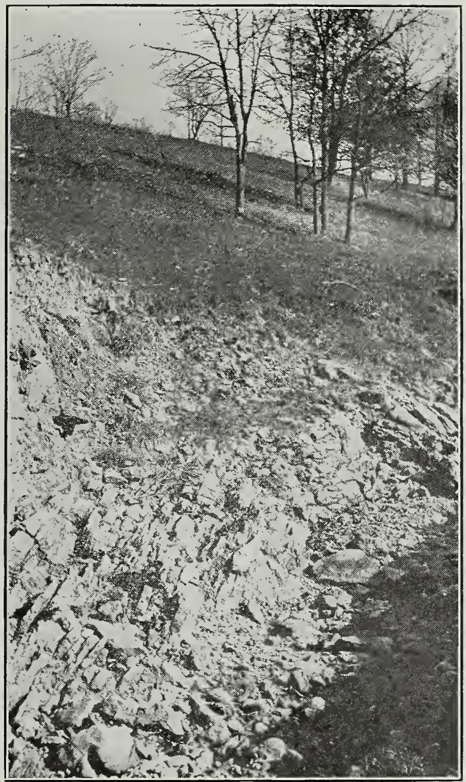

Fig. 10.—A close fold in the "Lower Magnesian" limestone along a tributary to Franklin Creek.

from outcrop. Detailed stratigraphic studies in connection with investigations in the Dixon quadrangle may reveal structure not now apparent. In places however, there is evidence of deformation. Observations in the Franklin Creek region in Lee County indicate that in this region also there was movement of the "Lower Magnesian" prior to St. Peter time. Along one of the tributaries of Franklin Creek in the NE. ¼ sec. 33, T. 22 N., R. 10 E., there is exposed in the bed of the stream a sharp fold in the

limestone (fig. 10) bearing S. 75° W. The rocks on the northeast side of the axis are nearly horizontal, but those on the opposite side dip about 45°. Farther up the ravine the limestone dips about 5° to 8°, S. 25° to 30° W. Along Franklin Creek near the center of the NE. ¼ sec. 33 the "Lower Magnesian" strata dip west 12° to 15°. At this latter place the sandstone lies directly above, but its structure could not be determined. Nowhere in Lee or Ogle counties did the St. Peter sandstone appear as closely folded as is the limestone below the St. Peter along Franklin Creek. Moreover, the structures of the older formation have a different bearing from those of the St. Peter which latter trend nearly N. 30° W.

ST. PETER SANDSTONE

The St. Peter sandstone is widely exposed in several areas in northern Illinois affected by deformation and therefore excels the "Lower Magnesian" as a basis of measuring regional deformation. On the other hand, because of rarity of good bedding planes in the sandstone, the details of the structure are less definite than they are in the overlying and underlying dolomites.

LA SALLE REGION

In places in the La Salle region, as at Split Rock and Deer Park, dips of 25° to 30° can be observed in the sandstone bedding along the west limb of the anticline. In general, however, the structure of this formation is most readily determined in this and other regions by observing the change in the altitude of its upper surface. Any change will have structural significance, as the relief of the surface of the sandstone due to the unconformity between the sandstone and the overlying Platteville formation is apparently not great, being no more than sufficient to bring about locally the omission of the "lower buff" or "quarry" beds having a thickness of about 25 feet. Where the "Coal Measures" strata rather than the Platteville formation rest upon the sandstone along the Illinois valley the contact surface is practically coincident with or at least nearly parallel to the surface upon which the Platteville was deposited, since remnants of the lower beds of the Platteville are found in many places lying between the "Coal Measures" and the sandstone.

The variation in the altitude of the surface of the St. Peter sandstone may be observed in three directions, namely, to the east, along the axis of the deformation to the south, and to the west. The variations, except to the west, may be expressed in feet per mile rather than in degree of dip. The structure will be described in the order indicated at the beginning of the paragraph.

The observed difference in the altitude of the surface of the sandstone between Utica and Ottawa, a distance of about 9 miles, amounts to

about 110 feet; however, about 90 feet of this decrease in altitude takes place in the first six and one-half miles east of Utica, the average dip for that distance being 15 feet per mile. The southward pitch of the sandstone along the crest of the anticline as determined from the altitude of the surface of the formation is steeper than that to the east. The highest altitude of the sandstone along the south bluff of the Illinois between Little Rock and Starved Rock is about 620 feet above sea level. Along

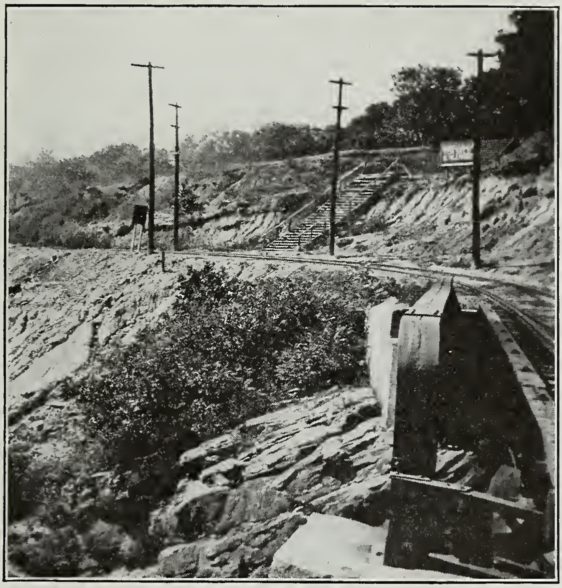

FIG. 11.—Outcrop of St. Peter sandstone overlain unconformably by Pennsylvanian strata at Split Rock. The dip of the St. Peter sandstone (20 to 30 degrees) is shown in the strata in the foreground. The dip of the Pennsylvanian (12 to 15 degrees) is shown by the ledge of sandstone outcropping under the stairs. Figure 13, also at Split Rock, presents diagrammatically and in more detail these same relationships.

Vermilion River about half a mile above the bridge at Lowell the Galena-Platteville formation lies nearly if not quite horizontal at an altitude of 510 feet. Accordingly, the surface of the sandstone has declined in altitude at least 100 feet in three miles. A record of an old boring for oil in the SE. ¼ sec. 9, T. 32 N., R. 2 E., reports 170 feet of Platteville-Galena at this place.[1] If this log is reliable there is a difference in the altitude of the sandstone between Lowell and Deer Park of about 270 feet, or a slope of 90 feet per mile. Along the north bluff of the Illinois, the

[1] Ill. Geol. Survey, vol. 3, p. 276.

top of the "Lower Magnesian" limestone has an altitude of about 600 feet in sec. 12, T. 33 N., R. 1 E., two miles east of La Salle, but it may be that the St. Peter was of less than usual thickness at this place, the older formation possibly having a sufficient relief locally to nearly penetrate the overlying sandstone. Hence it may be doubted that the surface of the sandstone was ever as high as 700 feet above sea level at this place. Concerning the inclinations observed on the west limb of the anticline, it has already been mentioned that dips as high as 25° to 35° have been measured.

An irregularity in this westward dip warrants special description. At several places along the west limb of the anticline the sandstone shows a conspicuous increase in dip part way down the slope. For instance, at Deer Park the altitude of the sandstone about the center of the S. ½ sec. 32, T. 33 N., R. 2 E., is between 600 and 605 feet above sea level. About 2,000 feet west the altitude of the sandstone is 550 feet, the average dip between the two points being 2.5 feet per 100. The altitude 500 feet farther west is 510, the average dip in this interval being 7.5 feet per 100. In the next 250 feet the altitude declines to 450 feet, the average dip being 20.4 feet per 100. Of this last 60 feet of change in altitude at least one-half takes place in the last 50 feet of distance, in which space the dip increases suddenly from 5° or 6° to about 20°. This sudden increase in dip is such as to produce in places an appreciable elbow in the surface of the sandstone. The position of change can be observed at certain places south of the Illinois as in Deer Park, in the ravine immediately south of Deer Park (Clayton's Ravine), and in one or two gullies north of the park along Vermilion River in sec. 30, T. 33 N., R. 2 E. It also is evident north of the Illinois at Split Rock and along Little Vermilion River in the NE. cor. sec. 3, T. 33 N., R. 2 E., and near the center of the N. ½ sec. 27, T. 34 N., R. 1. E., where the conditions are similar to those at Deer Park.

LEE AND OGLE COUNTIES

The structures of the St. Peter sandstone observed in Lee and Ogle counties are all relatively gentle, dips greater than 10° being uncommon. The bedding of the sandstone is obscure and cross-bedding possibly exists, so that the determinations of structure on the basis of the apparent inclination of bedding are not reliable. Just as in the La Salle region, the structure is determined more satisfactorily by noting the change in the altitude of its contact with the overlying Platteville formation. This is best observed on the west side of the uplift.

The slope of the surface of the St. Peter sandstone down the dip from Grand Detour to Rock River two miles above Dixon is at the rate

of about 85 feet per mile. The change in altitude from Pine Creek, near the center sec. 15, T. 23 N., R. 9 E., to the center of the west line of sec. 8, T. 23 N., R. 1 E., a distance of 3½ miles, is about 40 feet per mile (700 to 840 feet above sea level). North of Oregon the sandstone dips from an altitude of 850 feet near the north line of sec. 1, T. 23 N., R. 10 E., to an altitude of 690 feet about 1¼ miles north, or about 112 feet to the mile. This is the greatest change in the altitude of the surface of the sandstone that has been observed in outcrop in Lee and Ogle counties.

The structure of the sandstone on the east side of the line of maximum elevation in Lee and Ogle counties is not determinable from outcrop. The top of the sandstone is known to have an altitude of about 800 feet in the center of sec. 27, T. 22 N., R. 10 E., but the drift obscures the rock farther east, and structures can be determined only by drilling.

PLATTEVILLE AND GALENA LIMESTONE AND DOLOMITE

LA SALLE REGION

Like the underlying sandstone in this region these limestone formations show three directions of inclination, to the east, to the south, and to the west. The Platteville and Galena formations are found outcropping in the La Salle region on the west flank of the anticline near Illinois River and northward along the Little Vermilion. They extend over the crest of the fold south of the Illinois, and outcrop at places along the Vermilion as far south as Lowell. They are also known in small areas on the relatively flat east limb of the anticline nearly as far east as Minooka.

The dip to the east is gentle and outcrops indicate that there is a narrow syncline or monocline between Ottawa and Buffalo Rock crossing the Illinois valley northward from near the mouth of Covel Creek. East of Covel Creek the Platteville-Galena is next found exposed along Aux Sable Creek in sec. 18, T. 34 N., R. 8 E. The stratigraphic relationships are such as to suggest the presence of a slight uplift in the direction of Minooka, the strata rising from a broad syncline the lowest part of which, as indicated by drilling, is about at Seneca. The southward pitch of the limestone is probably the same as the sandstone below, namely 30 to 90 feet per mile between the Illinois valley and Lowell. Along the west flank of the fold the strata are inclined as much as 35° in some places, especially at Split Rock and Deer Park. South of Deer Park the exposures are higher on the flank of the fold and the dips of the exposed strata are not as great. At Lowell for instance they do not exceed 20°.

The exposures of the Platteville and Galena formations show a variation in strike along the west flank of the anticline. North of the Illinois along Little Vermilion River in the SW. ¼ sec. 22, T. 34 N., R. 1 E., and in the N.½ sec. 27 of the same township, at Split Rock, and south of the river at Deer Park the strike of the limestone is about N. 30° W. This approximates the strike of several outcrops of St. Peter sandstone between the Illinois and the mouth of Tomahawk Creek on the Little Vermilion near the center sec. 34, T. 34 N., R. 1 E. In sections 27 and 22 of the same township the strike of the Platteville swings off to the west becoming more nearly northwest in the NW. ¼ sec. 22. South of Deer Park likewise the strike swings off in the same direction, the Galena along Vermilion River at Lowell dipping approximately S. 30° W. Thus the line of strike appears as an open double curve which from north to south is directed first northwest-southeast, then more nearly north and south and then again northwest-southeast.

FOX RIVER REGION

Bannister[1] described the structure of the Platteville-Galena formations along Fox River in 1870 and presented a structure section from Montgomery to Milford, now Millington. Concerning the structure in sec. 8, T. 36 N., R. 6 E., he says:

"Below this place [sec. 8, T. 36 N., R. 6 E.] for some distance the strata of this age are met with and are doubtless tilted up by a small anticlinal the crest of which has most probably been eroded away. The evidence of this fold is in the existence of an exposure of the underlying St. Peter sandstone on the opposite side of the river in the southeastern quarter of section 17, and above the next exposure of the Trenton group and not by any decided dip of the strata in any direction."

Another structure farther down the river is also described:

"One mile above Milford [now Millington], on the right bank of the river, is Brodie's quarry, where the thickness of over 12 feet of rock is exposed * * *. This exposure is on the northeastern slope of still another anticlinal than the one before mentioned, the strata having an inclination of between 12 and 15 degrees in the direction N. 60° E. This is further proved by exposures of St. Peter sandstone along the river bluffs immediately below this point * * *"

LEE AND OGLE COUNTIES

The structure of the Platteville-Galena formations in Lee and Ogle counties shows the effect of the major uplift and also of the minor deformations such as those at Oregon, Leaf River, and in the Elkhorn Creek basin. Except near Oregon the exposures are almost entirely

[1] Bannister, H. M., Geology of Kendall County: Geol. Survey of Ill. vol. 4, pp. 143-146.

restricted to the east flank of the deformation. Those of especial interest are located near Lee Center and at Amboy, along Rock River between Dixon and Grand Detour, and along Pine Creek, on both sides of the Rock near Oregon, near Leaf River, and in the Elkhorn Creek basin.

At the exposures in southern Lee County near Lee Center and Inlet the rocks dip almost inappreciably to the west. The best indication of the dip is the exposure of the St. Peter sandstone near the center sec. 33, T. 21 N., R. 11 E., and the outcrop of the ferruginous beds near Amboy such as are found near the top of the Galena formation.

The bluffs of Rock River at Dixon and for two miles above are formed by the limestone and dolomite of the Platteville-Galena formations. A dip of 1° to 2°, S. about 60° W., is general along the river as far north as the mouth of Pine Creek (sec. 10, T. 22 N., R. 9 E.) (see Plate I). This seems to be the prevailing amount and direction of dip between Dixon and Grand Detour. Along Pine Creek the structure is somewhat irregular due to what is apparently a syncline which crosses the valley in sec. 34, T. 23 N., R. 9 E. Farther north a poorly defined uplift brings the St. Peter sandstone to the surface in secs. 14, 15, 22, 23, and 27. Elsewhere along Pine Creek the strata are apparently flat-lying.

The transverse anticline crossing Rock River valley at Oregon has been mentioned; the Platteville-Galena is especially serviceable in delineating this deformation and in showing its relation to the main anticline. The descriptive matter which follows is to a large extent shown graphically in the accompanying sketch map (Plate I). The structure of the limestone will be described in its outcrop around the rim of the basin, beginning at the north side near Oregon and continuing to the west, south, and east sides.

The north edge of the St. Peter sandstone area of the Oregon basin is defined by a continuous line of hills formed by the rim of Platteville-Galena and broken only by the valley of the Rock. These strata have northward dips as high as 25° in places. The west side of the basin is also bounded by hills of limestone which dips gently to the west at an inclination sufficient to bring the Galena dolomite below stream level along Pine Creek in sec. 4, T. 23 N., R. 9 E., at an altitude of about 725 feet above sea level. Near the west end of the south side of the basin the altitude of the base of the Platteville dolomite in secs. 7 and 8, T. 23 N., R. 10 E., is about 810 feet. Toward the east along the south rim the escarpment terminates in a ridge known as the Devil's Backbone, the east end of which overlooks Rock River. East of the river the south escarpment faces Kyte River valley which is the eastward continuation

of the Oregon basin. This line of hills is offset about 2½ miles south, and runs east along the south line of sec. 28, T. 23 N., R. 10 E., to sec. 25 east of which the rock topography becomes obscured under the drift. The offset seems to be due to a small monoclinal fold extending parallel to the main axis of elevation through the E. ½ sec. 22, T. 23 N., R. 10 E. The strata in this monocline which outcrop in a line of hills elongated parallel to the strike of the strata dip 10° to 12° about N. 50° E. One result of the deformation in section 22 has been to enhance erosion where the rock has been loosened by folding, so that a small basin of the same type as the Oregon basin is produced in the W. ½ sec. 22, faced by an escarpment of Platteville-Galena dolomite to the east. East of this hill the beds become horizontal, as shown in the isolated mesa-like hill in sec. 23. The structure of the east side of the Oregon basin is indeterminable from outcrop, as the valley of Kyte River is deeply filled with drift.

North of the town of Leaf River, St. Peter sandstone and the Platteville limestone are exposed in the S. ½ sec. 25 and in the SE. ¼ sec. 23, T. 25 N., R. 9 E. In the SE ¼ SW ¼ sec. 25 the Platteville strata overlying the sandstone dip about 8° S. 35° W., the top of the sandstone attaining an altitude of 790 feet above sea level. Similar strata near the center of section 25 dip about northwest 2° to 3°, so that the rise of the sandstone indicated by the dip observed at the first station is not continued far. Thin-bedded, bluish dolomite is exposed along the road in the SW. ¼ sec. 19, T. 25 N., R. 10 E., at an altitude of about 870 feet (Bar.) so that it is probable that the strata are as elevated here as in sec. 25. No evidence of the southward continuation of the structure was observed in sections 31 and 32, T. 25 N., R. 10 E.

The structure of the Elkhorn Creek area of St. Peter sandstone and overlying Platteville limestone has been adequately described by Hershey, as reviewed in Chapter II. The structure map presented by Hershey is reproduced in Plate I.

STRUCTURE OF STRATA INTERMEDIATE BETWEEN THE GALENA LIMESTONE AND THE PENNSYLVANIAN SYSTEM

The structure with reference to the anticline of the different formations occurring in the State younger than the Galena dolomite and older than the Pennsylvanian is determinable only by drilling. These rocks are not exposed adjacent to the axis of the deformation and outcrop only to the east or west where strata have only very gentle dips scarcely measureable in outcrop.

Structure as Determined by Drilling

PRELIMINARY STATEMENT

The use of drilling records in the study of geology structure greatly enhances the knowledge obtained from outcrop alone. Numerous records of deep wells have been studied during the progress of these investigations; by plotting the information obtained from these records and combining the data with that obtained from outcrops it is possible to construct a structure contour map showing the form and position of the anticline in so far as the deformation affects the stratum used as a structure plane.

The distribution of drilling is erratic. There are numerous deep wells for water in the northern part of the State as far south as Streator, and many test holes for oil and gas in Clark, Crawford, and Lawrence counties. Elsewhere the drilling has commonly not been deep enough to penetrate pre-Pennsylvanian rocks, especially in the central portion of the State. Some of the wells are located in areas that have been carefully studied, where quadrangle surveys have been made and investigations have been sufficient to determine the structure of the rocks. The results of these studies as published or as prepared for publication are freely drawn upon for this description, with proper credit assigned.

The surface of the St. Peter sandstone rather than some other stratum is used as a structure datum because of (1) the general distribution of the sandstone over the anticline, (2) the definiteness of the datum plane, the top of the sandstone being commonly recognizable by the driller as soon as reached, and (3) the numerical preponderance of the wells that reach this stratum as compared with the number of those that reach the Cambrian sandstone. Sufficient data are obtainable to warrant the construction of a structure map (Pl. II) showing the altitude of the surface of the St. Peter sandstone nearly as far south as Bloomington in the trough of the fold. The structure of the sandstone over a large area in the western portion of the State has also been delineated. In Crawford and Lawrence counties on the other hand the pre-Pennsylvanian structure is determinable only from the altitude of the Mississippian rocks, and hence the contours showing the altitude of the St. Peter sandstone do not continue this far south on the map.

STRUCTURE MAP OF THE SURFACE OF THE ST. PETER SANDSTONE

PRELIMINARY STATEMENT

The structure map of the St. Peter sandstone represents the maximum known deformation along the La Salle anticline and shows the effect of a series of movements that have taken place since St. Peter

time. Obviously the map does not show the effect of any movements that may have taken place before St. Peter time, since the altitude of the sandstone could not have been affected by such movements. Data are lacking to show whether there is greater displacement of the lower formations than of the St. Peter sandstone. This determination awaits more extensive drilling into the lower formations. When such data become available it is believed that the map presented herewith will be of service in determining facts relative to pre-St. Peter deformation.

PRESENTATION OF DATA

In the following table are given the location of the various wells, logs of which were used in the construction of the structure map, the altitude of the surface, the depth to and altitude of the sandstone. The surface altitude where determined by others than the writer is so indicated by the initials A., S., M., L., U., W., B., or P., referring to C. B. Anderson, T. E. Savage, W. C. Morse, Frank Leverett, J. A. Udden, K. D. White, O. F. Brooks, and E. H. Pool respectively. The surface altitude of other wells is estimated from railroad elevations, topographic maps, etc. Such estimates are liable to error of as much as 50 feet, but this figure is probably not much greater than the average error from all sources.

Table 30.—*Well data showing the altitude of the St. Peter sandstone*

County	Location and ownership of well	Surface altitude	Depth to sandstone	Altitude of sandstone
		Feet	*Feet*	*Feet*
Boone.......	Belvidere (C. N. & W. Ry.)	790[a]	355	+435
	Belvidere (City).........	(A) 750	340	+410
Bureau......	DePue (M. P. Zinc Co.)..	472	Below 1359	Below—887
	Princeton (City No. 1)...	700	1,700?	—1,000
	Princeton (City No. 2)...	700	1,521?	—821
Calhoun.....	Cap au Gres.............	550	Outcrop	+550
Carroll......	Mt. Carroll (City).......	775[a]	...	...
	Savanna (City)..........	595	325	+270
Cass.........	Beardstown (City)	440[a]	1,055	—615
Champaign..	Champaign (City?).......	740[a]	Below 1,833	Below—1,093
	Mahomet (sec. 14, T. 20 N., R. 7 E.)............	710	Below 1,000	Below—300
	Pesotum (Village).......	720[a]	About 1,740	About—1,020
Clark.......	Casey (Shover No. 1).... (sec. 1, T. 10 N., R. 14 W.)	550[a]	Below 3,017	Below—2,467
	Casey (Miller No. 1)..... (sec. 7, T. 9 N., R. 14 W.)	...	Below 2,379	Below—1,800

TABLE 30.—*Well data showing the altitude of the St. Peter sandstone—Continued*

County	Location and ownership of well	Surface altitude	Depth to sandstone	Altitude of sandstone
		Feet	*Feet*	*Feet*
Cook........	Argo (Corn Products Refining Co.)	(A) 590	800	—210
	Berwyn (City)	(A) 605	845	—240
	Blue Island (City)	(U) 641	908	—267
	Chicago			
	Amer. Colortype Co..... (Roscoe & Racine)	590[a]	910	—320
	Amer. Malting Co...... (Division & Chicago)	590[a]	895	—305
	Amer. Malting Co...... (Tolman & 12th)	590[a]	862	—272
	Armour Glue Works....	590[a]	918	—328
	Best Brewing Co....... (Fletcher & C. M & St. P. tracks)	590[a]	940	—350
	Bishop Babcock & Co... (1616 Burlington Ave.)	590[a]	897	—307
	Brand Brewing Co...... (2530 Elston Ave.)	(A) 591	856	—265
	Chicago Post Office.....	590[a]	905	—314
	Crystal Ice Co.......... (1461 Clybourn Ave.)	590[a]	890	—300
	Edelweiss Restaurant... (63 W. Madison St.)	590[a]	893	—303
	Fortune Bros. Brewery. (412 S. Desplaines St.)	590[a]	890	—300
	Gottfried Brewery...... (337 Alexander St.)	590[a]	897	—307
	Graceland Cemetery....	600[a]	900	—300
	Illinois Vinegar Co..... (48th & Oakley)	590[a]	850	—260
	McCormick Reaper Co.. (26th & Blue Island)	590[a]	830	—240
	Lake Shore Depot...... (Van Buren & La Salle)	590[a]	890	—300
	Lincoln Park..........	590[a]	925	—335
	Mullens Brewery....... (3937 Wallace St.)	590[a]	910	—320
	Oscar Meyer, Packers.. (1241 N. Sedgewick)	590[a]	936	—346
	National Brewing Co.... (1908 W. 18th St.)	590[a]	878	—288

TABLE 30.—*Well data showing the altitude of the St. Peter sandstone—Continued*

County	Location and ownership of well	Surface altitude	Depth to sandstone	Altitude of sandstone
		Feet	*Feet*	*Feet*
Cook—Cont..	Nutriment Company.... (49th & Halsted)	590[a]	905	—315
	Sears, Roebuck & Co.... (Harvard & Homan)	(A) 590	998	—408
	Sieben Brewing Co..... (Blackhawk & Larrabee)	590[a]	900	—310
	Spielman Bros......... (Clybourn & North)	590[a]	895	—305
	Stock Yards—			
	Adler & Obendorf....	(A) 592	880	—288
	Armour & Co.........	(A) 592	860	—268
			890	—298
			900	—308
	Darling & Co.........	(A) 592	870	—278
			875	—283
	G. H. Hammond & Co.	(A) 592	900	—308
			902	—310
			922	—330
	Independent Packing Co.	(A) 592	885	—293
	Nelson Morris Co.....	(A) 592	896	—304
			930	—338
	Sulzberger & Sons Co.	(A) 592	855	—263
	Swift & Co...........	(A) 592	876	—284
			880	—288
	Union Cold Storage Co...	590[a]	985	—395
	U. S. Brewing Co......... (12th & Sangamon)	590[a]	914	—324
	Watkins, Vincent & Fretts (Center & Superior)	590[a]	900	—310
	Western Electric Co......	600[a]	860	—260
	White Eagle Brewery Co.. (38th & Center)	590[a]	885	—295
	White Eagle Brewery Co.. (18th & Ashland)	590[a]	880	—290
	Clearing	(A) 617	870	—207
	Desplaines (Norma)...... (C. & N. W. Ry.)	(A) 655	700	—45
	Dolton (City)...........	610[a]	885?	—273 (310?)
	Evanston (City)	...	...	—222
	Galewood (C. M. & St. P. R. R.)	640[a]	853	—213

TABLE 30.—*Well data showing the altitude of the St. Peter sandstone*—*Continued*

County	Location and ownership of well	Surface altitude	Depth to sandstone	Altitude of sandstone
		Feet	*Feet*	*Feet*
Cook—Cont..	Godfrey Yards (C. M. & St. P. R. R.)	612[a]	800	—188
			808	—196
			805	—193
	Hawthorne (C. B. & Q. R. R.)	605[a]	845	—240
	Kensington (Sherwin Williams Paint Co.)	590[a]	924	—334
	Kensington (American Malting Co.)	(A) 590	945	—355
	La Grange (Western G. & E. Co.)	645[a]	Below 790	Below—145
	Oak Park (N. W. G. Coke & L. Co.)	625[a]	892	—267
	Park Ridge (Village)	(A) 660	820	—160
	Proviso (C. & N. W. Ry.)	(A) 643	810	—166
	South Chicago (Ill. Steel Co.)	590[a]	965	—375
	South Chicago (Columbia Malting Co.)	585[a]	986	—401
	Summit (Village)	(A) 600	804	—204
	Washington Heights	615[a]	920	—305
Cumberland..	Casey (Chrysler No. 30)	...	Below 1,880	Below—1,200
De Kalb	De Kalb (City)	(A) 865	524	+341
	DeKalb (Amer. Steel & Wire Co.)	885[a]	570	+315
	Malta (C. & N. W. Ry.)	(A) 915	500	+415
	Sandwich (City)	(A) 667	397	+270
	Somonauk (Village)	(A) 690	106	+584
	Sycamore (Electric Co.)	(A) 840	535	+305
Douglas	Tuscola	650[a]	...	Below—1,350
Dupage	Bensenville (C. M. & St. P. R. R.)	(A) 680	805	—125
			785	—105
	Downers Grove (City)	(A) 717	817	—100
	Elmhurst (City)	(A) 677	790	—113
	Naperville (City)	(A) 677	646	+31
	West Chicago (C. & N. W. Ry.)	(A) 740	724	+16
Fulton	Canton (Parlin & Orendorff Plow Co.)	(S) 655	1,445	—780
	Ipava	(L)	...	—630
Greene	Carrollton	(L)	...	—590

TABLE 30.—*Well data showing the altitude of the St. Peter sandstone—Continued*

County	Location and ownership of well	Surface altitude	Depth to sandstone	Altitude of sandstone
		Feet	*Feet*	*Feet*
Grundy......	Coal City (E. J. & E. R. R.)	565[a]	600	—45
	Mazon (Ed Walker)......	(A) 600	620	—20
	Minooka oil well.........	...	440	...
	Morris (City)...........	(A) 503	330	+173
	Morris (Abe Hoge)......	590[a]	277	+313
Hancock.....	Carthage	(L)	...	—297
Henry.......	Alpha (City)	811[a]	1,213	—400
	Cambridge (City)........	812[a]	1,275	—463
	Cambridge (Infirmary)...	812[a]	1,205	—493
	Geneseo (City)	(U) 645	1,075	—430
	Kewanee (City)..........	850[a]	1,345	—495
	Kewanee (Power house)..	850[a]	1,269	—419
	Kewanee (Western Tube Co.)	850[a]	1,310	—460
	Woodhull (City)	824[a]	1,266	—442
(Indiana)...	Hammond	(L)	...	—460
	East Chicago (Grasselli).	(A) 587	1,116	—529
(Iowa)......	Davenport	(L)	...	—370
	Keokuk	(L)	...	—316
Iroquois.....	Gilman (City)	654[a]	1,350	—696
	Sheldon (City)	688[a]	1,350	—662
Jersey.......	Jerseyville	(L)	...	—738
Jo Daviess...	Galena (City)	600[a]	160	+440
	Galena (sec. 16, T. 28 N., R. 1 E.)...............	600 (Folio 200)	120	+480
Kane........	Aurora (City No. 8)......	(A) 630	610	+20
	Batavia (City; new well)	(A) 660	520	+140
	Elburn (City)	(A) 848	614	+234
	Elgin (City)............	(A) 738	560	+178
	Elgin (City)............	(U) 740	640	+100
Kankakee....	Kankakee (Asylum)	(A) 615	895	—280
Kendall......	Millington	(L) 600	Outcrop	+600
	Plano (along Fox River).	575[a]	550	+25
Knox........	Galesburg (Purington Paving Brick Co.)......	750[a]	1,090	—340
Lake........	Blodgett (C. & N. W. Ry.)	650[a]	805	—155
	Grays Lake (Wisconsin Condensed Milk Co.)...	800[a]	840	—40
	Highwood (C. Mil. Elec.).	680[a]	970	—290
	Lake Bluff	(L)	...	—258

TABLE 30.—*Well data showing the altitude of the St. Peter sandstone—Continued*

County	Location and ownership of well	Surface altitude	Depth to sandstone	Altitude of sandstone
		Feet	*Feet*	*Feet*
Lake—Cont..	Lake Forest (Ogden Armour)	(A) 690	875	—185
	Ravinia Park	(A) 675	886	—211
	Rondout (C. M. & St. P. R. R.)	680[a]	960	—280
	Waukegan (Amer. Steel & Wire Co.)	600[a]	860	—260
	Zion City (City)	(A) 648	850	—202
La Salle	Cedar Point (Mine No. 5)	653	1,610	—957
	Deer Park	455	52	+403
	La Salle (E. of Split Rock)	450[a]	Eroded	...
	La Salle (M. & H. Zinc Co.)	585	1,487	—902
	Lowell (Bottomly mine)	500	358	+142
	Marseilles (Peddicord)	710	359	+351
	Mendota (City)	(B) 760	440	+320
	Oglesby (Village)	(A) 642	1,540	—902
	Oglesby (Ch. Port. Cem. Co.)	605	1,530	—925
	Ottawa (City)	484	9	+475
	Peru (Ill. Zinc Co.)	(A) 463	1,363	—900
	Peru (St. Bede College)	(U) 609	1,525	—916
	Seneca	(L)	...	+250
	Sheridan (City)	...	16	...
	Streator (City)	623	444	+279
Lee	Dixon (Epileptic Colony)	805[a]	95	+710
	Dixon (Epileptic Colony)	805[a]	72	+733
Livingston	Chatsworth (City)	736[a]	1,210	—474
	Cullom (City)	689[a]	1,280	—591
	Dwight (Keely Inst.)	641[a]	795	—154
	Odell (City)	721[a]	1,000	—279
Madison	Collinsville (Peter Stifel)	562	Below 2,147	Below—1,580
Marshall	Henry (City)	491[a]	Below 1,355	Below—864
McDonough	Bushnell (City No. 2)	(M) 651	1,215	—564
	Macomb (City)	700[a]	1,135	—435
	Macomb (Sewer Pipe Co.)	700[a]	Below 820	Below—120

TABLE 30.—*Well data showing the altitude of the St. Peter sandstone—Continued*

County	Location and ownership of well	Surface altitude	Depth to sandstone	Altitude of sandstone
		Feet	*Feet*	*Feet*
McHenry....	Harvard (C. & N. W. Ry.)	(A)935	648	+287
	Woodstock (City No. 2)..	(A)915	796	+119
	Woodstock (City No. 3)..	915[a]	785	+130
	Woodstock (Oliver Typewriter Co.)	...	730	...
McLean......	Chenoa (City)	720[a]	1,430	—710
	Heyworth (oil test)......	750[a]	Below 2,150	Below—1,400
Mercer......	Aledo (City)	739[a]	1,098	—359
Morgan......	Jacksonville (City)	600[a]	1,535	—935
Ogle.........	Elkhorn Creek	(L)850	Outcrop	+850
	Polo (City)	900[a]	125?	+775?
	Rochelle (City)	790[a]	85	+705
Peoria.......	Peoria (Asylum)	(U)605	1,665	—1,060
	Peoria (Peoria Min. Co.).	(U)475	Below 1,417	Below—1,058
	Princeville (City)	745[a]	1,560	—815
Piatt........	Deland (City)	700[a]	Below 1,070	Below—300
Putnam.....	Putnam (C. W. Reed)....	(U)730	1,550	—820
	Taft (B. F. Berry Coal Co.)	680	1,600	—920
Rock Island..	Milan	(L)	...	—364
	Rock Island.............	(L)	...	—364
Sangamon...	Salisbury (oil test)......	535[a]	1,791	—1,256
	Springfield..............	590[a]	Below 1,500	Below—910
Stark........	Stark (City)	(P)800	1,598	—798
Stephenson..	Freeport (Franz Brewery)	824	267	+557
	Freeport (City)	747	136	+611
	Freeport (Stover Mfg. Co.)	759	160	+600
Vermilion...	Allerton (sec. 22, T. 17 N., R. 14 W.).............	698[a]	Below 920	Below—222
	Danville	...	Below 1,149	...
	Danville (C. & E. I. Ry.)...	(W)615	Below 2,008	Below—1,393
	Hall well (sec. 30, T. 18 N., R. 10 W.)..........	(W)611	Below 1,036	Below—425
	Holten well (sec 26, T. 17 N., R. 13 W.)..........	(W)650	Below 1,303	Below—653
	Richard well (sec. 20, T. 17 N. R. 11 W.)........	(W)663	Below 1,537	Below—874
	Ruddy well (sec. 11, T. 23 N., R. 14 W.)..........	(W)718	Below 1,475	Below—757
	Ruddick well (sec. 32, T. 23 N., R. 13 W.).......	(W)770	About 1,888	About—1,118

TABLE 30.—*Well data showing the altitude of the St. Peter sandstone—Concluded*

County	Location and ownership of well	Surface altitude	Depth to sandstone	Altitude of sandstone
		Feet	*Feet*	*Feet*
Warren	Monmouth	(L)	...	—336
Whiteside	Morrison (City)	670[a]	770	—100
	Sterling (Borden Con. Milk Co.)	645[a]	705	—60
Will	Braidwood (City)	(A) 581	645	—64
	Custer Park (City)	566[a]	500	+66
	Joliet (City) (Canal & Division)	(A) 552	620	—68
	Joliet (Dellwood Park)	...	747	...
	Joliet (Ill. Steel Co.)	545[a]	632	—88
	Lockport (City)	(A) 568	630	—62
	Rockdale (Village)	(A) 548	590	—42
Winnebago	Rockford (City No. 8)	(A) 728	248	+480

STRUCTURAL FEATURES OF THE PRE-PENNSYLVANIAN ROCKS AS SHOWN BY THE STRUCTURE MAP

THE STEEP WEST LIMB OF THE ANTICLINE

As shown by the structure map (Pl. II) the most conspicuous and continuous feature of the anticline is a belt of inclined strata extending in a sweeping curve from Savanna in Carroll County into the southeastern Illinois oil field. This portion of the fold is the feature commonly and popularly called the La Salle anticline, the features of the deformation as a whole not being taken into consideration. Except for the structure along this belt, where the rocks are in places inclined at angles higher than 35°, the inclinations of the strata involved in the fold as a whole are gentle, to be measured more commonly in terms of feet per mile than in degree of dip.

OGLE, LEE AND LA SALLE COUNTIES ANTICLINE

In the northern counties of the State, particularly in Ogle, Lee and La Salle counties, an elongated narrow anticline, along part of its course flanked on the southwest by a belt of speeply inclined strata just described, extends from Stephenson County west of Freeport through Elkhorn Creek uplift, Grand Detour, Franklin Grove, and terminates bluntly along Fox River valley near Millington and Sheridan. The deformation is

broad enough to include the Oregon basin and the uplift along Leaf River. The slopes along the east flank of the uplift are commonly very slight but between Millington and Yorkville and between Somonauk and Sandwich the average dip amounts to about 100 feet per mile, and dips of 10° to 12° have been observed.

SOUTHWARD PITCH OF THE FOLD

Southward from the Illinois valley the crest of the anticline pitches steeply to the south. The pitch in La Salle County amounts to as much as 30 to 90 feet per mile, a rate which exceeds the slight eastward dip of the strata in this county from 2 to 6 times. This southward pitch decreases in amount in Livingston County, and in the southern part of that county and northern McLean County and possibly as far south as Douglas County the pitch possibly does not average more than 6 to 8 feet per mile. From Douglas County south, however, there is another increment in the rate of pitch resembling that in La Salle County. Southward from La Salle County, moreover, the deformation tends to assume a more symmetrical form, the strata dipping more and more steeply to the east as the fold is followed to the south. Accordingly in Champaign and Vermilion Counties and southward in Edgar County there is a distinct basin to the east as well as to the west of the main axis of deformation. These basins form respectively the main parts of the Indiana and Illinois coal fields.

BASIN WEST OF THE ANTICLINE

The west limb of the anticline forms one side of a large basin comparable in dimensions with the arch on the east. This basin continues westward into Iowa[1] between Savanna and Burlington. Between the larger portion of the Illinois basin and the deeper portion of the Iowa basin is a broad dome the position of the east side of which in the western counties of the State is indicated on the structure map. Its eastern slope is rather distinctly suggested by the close spacing of the 600 and 800-foot contour lines a short distance west of the Illinois valley. A small contour interval would emphasize this close spacing. The main portion of the Illinois basin deepens and widens to the south joining an Iowa-Missouri basin south of Calhoun County.

There are certain minor characteristics of the trough or basin west of the anticline that may well be pointed out. Between Rock Island and La Salle the trough deepens rapidly in Bureau County. This steeper dip is apparently located along the northward continuation of the east

[1] Norton, W. H., et al., Underground water resources of Iowa: U. S. Geol. Survey Water Supply Paper No. 293, Pl. 1, 1912.

side of the western Illinois dome, and in Bureau County produces a difference in the altitude of the sandstone amounting to about 400 feet within a short distance, the change being from 500 to 900 below sea level. Southward from La Salle and Oglesby to Heyworth in McLean County there are no wells, of which there are reliable records, that penetrate strata older than the Pennsylvanian. Judging from the structure of the coal, however, it seems probable that there is no strong southward pitch of the pre-Pennsylvania strata in the trough at least as far south as Minonk. The sandstone lies at a depth of about 900 feet below sea level at La Salle, and since No. 2 coal is nearly 300 feet more in altitude at Minonk than it is at La Salle,[1] the greater part of the difference in altitude between the surface of the sandstone at La Salle and at Heyworth in McLean County, amounting to more than 500 feet, is probably due to increase in the rate of dip south of Minonk. Some indication of the depth of the basin in the southwest part of Livingston County about 15 to 18 miles southeast of Minonk is shown by the well at Colfax, in which the sandstone was struck 700 feet below sea level, or 200 feet higher than at La Salle. It has not been demonstrated that this well is located in the deepest part of the basin, hence the west limb of the fold is shown on the structure map as passing through Colfax at the position of the well.

The probable shallowing of the basin southward from La Salle, or at least the decrease in the rate of pitch, being paralleled by the steep southward pitch of the anticline through southern La Salle and Livingston effects a softening of the structure in southern Livingston and northern McLean counties so that the sandstone on the two sides of the west limb of the fold does not differ in altitude more than 600 to 800 feet. This may be compared with a difference of 1500 feet at La Salle.

Concerning the structure of the St. Peter sandstone south of Heyworth little knowledge is available, as the sandstone has nowhere been reached by the drill in the trough of the basin. Judging from the structure of the "Coal Measures", however, there is a rapid deepening southward from Bloomington, so that in Champaign and Douglas Counties the difference in altitude of the surface of the sandstone in the trough and on the crest of fold is similar to if not greater than the difference found in La Salle County.

MINOR STRUCTURAL FEATURES EAST AND NORTH OF THE AXIS OF THE ANTICLINE

In northern Illinois deformations are present which trend transversely to the direction of the La Salle anticline as traced from Stephen-

[1] Cady, G. H., Coal resources of District I: Ill. Coal Mining Investigations Bull. 10, Pl. I, 1912.

son to Lawrence counties. The existence of folds crossing the southern part of Wisconsin and northern Illinois from east to west has been known for some time. Chamberlin[1], McGee[2], and Hershey[3] have commented upon or described these folds. Chamberlin [1] writes as follows:

"Notwithstanding the very evident fact of a broad low anticlinal arch extending south from the Archaean heights of Lake Superior, flanked by feeble undulations, it is a somewhat remarkable fact that the general strike of the Archaean folds and the prevalent trend of the minor anticlinals of the Paleozoic strata are east and west. * * * If for convenience, we regard the Laurentian nucleus as a resisting center, then the folds south of it were due to the force acting horizontally upon the strata from the southward."

Of the various minor folds in northern Illinois adjacent to the anticline and productive of structural features which make the main anticline somewhat difficult to trace or that overcome its effect, the following may be enumerated and described:

1. Savanna-Sabula anticline.
2. Stephenson-Ogle county-line syncline.
3. Aurora-Pawpaw syncline.
4. Morris-Kankakee anticline.

Savanna-Sabula anticline—The chief flexure crossing northern Illinois transverse to the direction of the La Salle anticline is the deformation the westward extension of which crosses into Iowa at Sabula. This anticline is described by McGee[4] and later more fully by Savage[5] and Carman[6]. In regard to the extension of this deformation McGee[4] states:

"It should be noted that not only is the uplift on Rock River described by Worthen almost exactly on the line of the anticlinal crossing the Mississippi near Sabula, but that the extension of the anticlinal well toward Rock River is proved by the exceptionally high altitude of the Trenton limestone between Sabula and Grand Detour."

Savage[5] describes the deformation in Iowa as follows:

"The conspicuous example of deformation that occurs in Jackson County consists of a low arch that extends in an eastwest direction from Savanna, in Illinois, to the east side of section 30 in Fairfield Township, a distance of

[1] Chamberlin, T. C., Geology of Wisconsin, vol. IV, pp. 425-427 and Pl. VIII, opposite page 399, 1882.

[2] McGee, W. J., Pleistocene history of northeastern Iowa: U. S. Geol. Survey 11th Ann. Rept., pt. 1, p. 338 ff., 1891.

[3] Hershey, Oscar H., The Elkhorn Creek area of St. Peter sandstone in northwestern Illinois: Amer. Geol., vol. 14, pp. 169-179, 1894; also Physiographic development of the upper Mississippi Valley, Amer. Geol., vol. 20, p. 246, 1897.

[4] McGee, W. J., Pleistocene history of northeastern Iowa: U. S. Geol. Survey 11th Ann. Rept. pt. 1, p. 340, 1891.

[5] Savage, T. E., Geology of Jackson County, Iowa: Iowa Geol. Survey, vol. 16, p. 640, 1905.

[6] Carman, J. Ernest, The Mississippi valley between Savanna and Davenport: Ill. State Geol. Survey Bull. 13, p. 10, 1909.

about twenty miles. The strata involved in the deformation embrace the Maquoketa shale and the overlying beds of Niagaran limestone.

The maximum height of the arch was in sections 29 and 30, Fairfield Township. At each of these points the aneroid readings gave the elevation of the upper layers of the Maquoketa as 175 feet above the corresponding layers in the vicinity of Preston. Readings at two different points in sections 22 and 23 of Van Buren Township gave the altitude of the uppermost Maquoketa layers as 90 and 115 feet respectively above the equivalent layers near Preston. At some points over this arched belt, where the upper layers of the Maquoketa beds are best exposed, they seem to have been thrown into a series of small crumples at the time the main arch was raised. Where well exposed the layers are crossed by two series of small parallel fissures. These fissures are six to twenty-four inches apart and extend for a distance of one to three or four feet. Those of one series have a direction nearly at right angles to those of the other. When the Niagara layers were seen in an apparently undisturbed position against the inclined Maquoketa beds the angle of dip was about thirty degrees. Between the different points, and sometimes in the same outcrop, the dip varies widely as regards both direction and inclination. A portion of this variance is probably due to the fact that the Niagara limestone creeps or settles on the shale when inequality of support results from differential erosion".

In 1909 J. Ernest Carman[1] presented a generalized structure section along the Mississippi valley from north of Savanna to south of Rock River showing the general position and character of the Savanna-Sabula anticline and describes the structure as follows:

"On the Iowa side of the river, the top of the shale has a nearly constant elevation from Lyons north to Jackson County. West of Sabula the bluff cuts across a low east-west anticline, and the upper contact of the shale has an elevation of 80 to 90 feet above the river. It dips in either direction and soon has its usual elevation of 40 to 50 feet above the river. At Savanna the surface of the shale on the anticline in the Illinois bluff is more than 100 feet above the river, while two miles farther north it has declined to within 25 feet of the river."

In the previous section of his report describing the extent and outcrops of the Maquoketa formation, he states, as follows:

" * * * on the Illinois side of the river the shale is first seen in the point of the bluff just to the north of Johnson Creek. It extends 40 to 50 feet above the road, up to an elevation of about 675 feet. In the northeast part of Mount Carroll Township, Carroll County, Illinois, in the region around Argo and southeast of Hickory Grove, the Maquoketa shale is the uppermost bed rock, although in the Mississippi bluffs to the west, limestone comes well down toward the base of the bluff and is the only rock exposed. These upland exposures occur at various elevations up to 750 to 775 feet."

"Along the river bluff between Lyons and Elk River the contact of the shale and overlying limestone is sharp and apparently horizontal. Just north of Lyons the contact dips (declines) to the south, and at Clinton is more than 100 feet below the level of the river".

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[1] Carman, J. Ernest, Mississippi Valley between Savanna and Davenport: Ill. State Geol. Survey Bull. 13, fig. 3, p. 11, 1909.

Besides the uplift along Rock River, evidence of the extension of a transverse anticline from the Savanna region farther east into Illinois is indicated by the structure described by Hershey as existing in the Elkhorn Creek area of St. Peter sandstone. He maps two axes of deformation or two crests to an anticline which possibly continues slightly north of east toward Leaf River. The position of these axes as determined by Hershey is shown in the map, Plate I. In 1897 Hershey presented a north-south cross-section through the basins of Leaf River and Elkhorn Creek which shows the form and position of the transverse deformation.[1]

Inspection of the structure map of the St. Peter sandstone presented in this report will reveal the probability of the extension of the Savanna-Sabula anticline eastward practically across the State. The rather obscure anticline extending east from Sycamore through South Elgin toward Highland Park is possibly the eastward extension of the deformation under discussion. It is this uplift which causes the outcrop of Richmond (Maquoketa) shale in the bed of Fox River between Batavia and South Elgin. It is along this axis also that the uplift of the Oregon basin is located, and to it is probably due the high altitude of the strata in the vicinity of Polo.

Stephenson and Ogle county line syncline.—The existence of a low syncline extending parallel to the Savanna-Sabula anticline and north of it along the line between Stephenson and Ogle counties has been pointed out by Hershey in his article on the Elkhorn basin. He states that the dip on the noth side of the Leaf River fork of the Savanna-Sabula anticline is about 100 feet per mile, or 1.7 degrees. "This", he says[2], "is soon decreased to about 40 feet per mile and so continues six miles to the axis of the next synclinal which lies on the Stephenson and Ogle county line. This synclinal is occupied by an upland ridge, underlain by Niagaran limestone, the edge of which is only four miles distant from the outcropping sandstone, and is less than 100 feet higher". The existence of this syncline is well shown on the structure map of the St. Peter sandstone by the curve of the 600-foot contour line in Winnebago and Stephenson counties.

Pawpaw-Aurora syncline.—Between Franklin Grove and Earlville is a synclinal structure which is persistent eastward as far as Aurora. The delineation of the structure in the vicinity of Pawpaw is indefinite, as the record of the well at Pawpaw can be variously interpreted. The syncline

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[1] Hershey, O. H., The physiographic development of the Upper Mississippi Valley, Amer. Geologist Vol. 20, p. 254, 1897.

[2] Amer. Geol. vol. 14, p. 177, 1894.

may be much more important than is shown if the first limestone, which is encountered at a depth of 455 feet, is Galena or Platteville rather than "Lower Magnesian" as is supposed. The structure is drawn on the basis of the later assumption. This syncline apparently has a relatively steep slope on the south especially between Somonauk and Sandwich and between Millington and Yorkville.

Morris-Kankakee anticline.—From the eastward end of the blunt termination of the anticline running through Ogle, Lee and La Salle counties there extends a low arch along an axis from near Sheridan towards Morris and Kankakee. The occurrence of oil in the strata near Coal City is apparently partly occasioned by this structure. The fold apparently becomes broad and scarcely distinguishable southeast of Kankakee and is only to be differentiated because between it and the main axis of the La Salle anticline is the shallow syncline which possibly represents the northward continuation of the Indiana coal basin.

STRUCTURE OF THE PRE-PENNSYLVANIAN ROCKS IN CLARK, CRAWFORD AND LAWRENCE COUNTIES

GENERAL STRUCTURAL RELATIONS

The structure of the pre-Pennsylvanian rocks across the anticline in the counties south of Livingston County can be determined with only a rough approximation to accuracy. Enough drilling has been done so that the position of the crest of the deformation can be fairly well indicated through Champaign, Douglas, and Coles counties. But even in these counties its exact position cannot be located within possibly 5 miles. In Clark, Crawford, and Lawrence counties the case is not much better. Drilling is very definitely limited along the west side of the line of apparent maximum uplift, as strata commonly oil bearing along the axis of the fold rapidly pass below the level of oil saturation and into salt water, as the formations dip to the west. Because of this relation of water to the oil the west side of the oil field is commonly regarded as a close approximation to the axis of the deformation.

The amount of displacement by folding along the anticline and the form of the structure as a whole down to the foot of the west limb cannot be determined much more satisfactorily in Clark, Crawford and Lawrence counties than in Douglas and Champaign counties. As in the latter region the west flank is thought to slope abruptly into the trough, but drilling necessary to determine the length and angle of the slope has not been done, and even the depth of the trough can only be inferred from holes located some distance from the crest. Because of this in-

definiteness the structure contour maps showing the anticline in the southern part of the State possibly delineate a more gentle structure than actually exists, as possibly the trough of the fold is crowded closer toward the crest than is shown on the maps. On the other hand the present indefiniteness concerning the position and form of this west slope leaves room for the chance that somewhat adventurous drilling adjacent to, but west of, the main field may discover a terrace or even a secondary crest in places west of the present supposed line of maximum elevation and crest of the anticline. Toward the southern part of the fold where the structure becomes somewhat indefinite, this is more likely to be the case than it is in Clark or Crawford Counties. The Allendale pool may be cited as an example of a field located essentially by wildcatting west of what was once supposed to be, and possibly is, the main crest of the anticline.

Structure maps of the pre-Pennsylvanian strata in the oil fields have been constructed for the Tracy, Kirkwood, and McClosky sands. The two former sands are of the Chester group and the latter is an oolitic limestone near the top of the Mississippian "Big Lime" and representing stratigraphically the Ste. Genevieve limestone. These maps are applicable only to the main pools in Lawrence county and only the map based upon the altitude of the Kirkwood sand can be said to be definitely established. The structure of this sand in Lawrence County as determined by previous investigators is shown in Plate III. The structure of the Pennsylvanian sands cannot readily be delineated because of their apparent lenticular form and erratic distribution both horizontally and vertically. Accordingly structure maps of the pre-Chester, Chester and Pennsylvanian formations are not available as a means of comparing the structure and determining the amount of unconformity between the successive formations. Moreover, even the structure maps of the Kirkwood sand do not serve to show the form of the entire fold, because of the lack of drilling down the west flank. Drill holes to the west of the crest are not found beyond a line along which the sand lies more than 400 feet below its elevation along the crest, and, indeed, very few holes find the sand more than 300 feet below its altitude at the crest. The actual difference in altitude of the sand as between the crest and trough may be as much as 200 to 1500 feet, so that it is evident that only the upper part of the west slope has been explored. The structure maps are especially serviceable in showing the structure of the relatively gently sloping east flank of the anticline, and in outlining the secondary structures that are of much importance in determining the position of local oil pools.

There is no structure map showing the position of the oil sands northward from Robinson through Clark County. The developed sands are mainly shallow and of Pennsylvanian age. The Chester sands wedge out northward probably between Robinson and the Clark County line, and it is probable that the McClosky sand is also eroded below much of Clark County. Within the last two or three years a few deep wells in Clark County have penetrated to the Trenton (Galena-Platteville) limestone, but an insufficient number have been drilled to justify the construction of a detailed structure map based upon the altitude of the lower rocks. Even the upper productive sands do not appear to yield readily to delineation by structure contours because of their lenticular character. Accordingly the maps of the producing areas give the most definite indication of the trend and position of the anticline in this part of the southeastern Illinois oil field. As is the case farther south, drilling has been restricted along the west side of the field because the sands dip rapidly below the level of salt water; hence the west boundary of the field is commonly regarded as approximately along the crest of the anticline. Accordingly the axis is represented as passing along the west side of the Siggins Pool in Cumberland County (see Plate III), thereby throwing the northern Clark County (Westfield) pool somewhat to the east of the main axis.

The map of Clark, Crawford, and Lawrence counties shown herewith (Pl. III) indicates the boundary of the oil pools giving the names of several, shows the structure of the Kirkwood sand by contours on a sea level datum, and shows by figures the depth to several formations as indicated in the legend. Of the pre-Pennsylvanian formations referred to there are included the Galena-Platteville (Trenton) limestone, the Niagaran limestone, and the Mississippian "Big Lime". In each case the depths refer to the top of the formations. The data included in this map almost entirely concern the structure of the relatively flat east limb of the fold, but attention may be directed to certain characteristics of the pre-Pennsylvanian structure of that part of the deformation.

(1) The oil pools northward from Bridgeport are restricted to a relatively narrow belt apparently lying along or adjacent to the main axis of the deformation. It has been pointed out that exploration in these pools has been largely limited to the Pennsylvanian strata and hence to what extent the lower formations possess a rather definite anticlinal structure with a considerable dip on the east flank as well as on the west is not determined. However, in view of the apparent rather definite anticlinal structure through Champaign and Douglas counties whereby the strata are caused to dip definitely toward troughs on either

side, there exists a probability that similar conditions are continued into Clark County and control the form of the deformation. This supposition, however, from the nature and amount of information available is highly speculative. Certainly the data available do not serve to determine the form of the deformation of the older rocks across the arch in Clark and Crawford counties.

(2) Passing south into Crawford and Lawrence counties the structure of the older rocks indicates that the east limb becomes nearly horizontal, or at least is interrupted by irregularities not evidently present farther north. Investigations in Birds, Hardinville, Sumner and Vincennes quadrangles show, as will be outlined later, that anticlinal and synclinal structures diverge from the main axis of the fold and swing off toward the southeast as indicated by the general trend of the oil pools in those counties. In Crawford County the anticlinal structure beginning along the main anticline at the Kibbie Pool north of Oblong swings to the southeast terminating in the Flat Rock and Birds pools. In Lawrence County a second anticlinal structure starts along the main anticline in the Nuttall Pool and terminates to the southeast at St. Francisville. Between the Crawford and Lawrence counties fields lies the Embarrass River syncline. South of the Lawrence County field is another syncline directed toward the southeast, south of which again is the Allendale pool, along what is possibly the continuation of the main crest of the anticline.

(3) A third significant characteristic of the structure of the older rocks which merits attention is the varying rate of southward dip of the various formations, which is indicative of their unconformable relations. Inspection of the map (Pl. III) will show that the depth to the Mississippian limestone increases greatly to the south, from less than 1,000 feet in Clark County to more than 2,000 feet near St. Francisville. The depth to the coal beds on the other hand shows no such variation, the depth varying only from about 500 feet to possibly 800 feet lengthwise of the area. The interval between the Kirkwood and McClosky sands also increases southward. Prof. Savage points out that westward from the axis of the anticline in the Sumner and Vincennes quadrangles also, the Kirkwood and McClosky diverge.

It is believed that the foregoing paragraphs summarize the general structural relationships and conditions in the oil fields of southeastern Illinois. It is thought advisable to present briefly the results of detailed investigations of the structure of the pre-Pennsylvanian rocks as published or prepared for publication by members of the State Geological Survey.

STRUCTURE OF THE PRE-PENNSYLVANIAN ROCKS IN THE HARDINVILLE, BIRDS, SUMNER, AND VINCENNES QUADRANGLES

Detailed geologic work to determine the structure of the rocks in the southeastern Illinois oil field has been carried as far north as Oblong in Crawford County in the Hardinville, Birds, Sumner, and Vincennes quadrangles. These areas lie within parallels 38° 30′ and 39° and meridians 87° 30′ and 88°, and include the southern half of Crawford County and all of Lawrence County. This area was studied by Blatchley[1] who published a report upon it in 1913, and it was later restudied by Savage and Blatchley[2] and by Rich.[3] The later studies of the small units reviewed the earlier work by Blatchley, and the results represent the latest information relative to the structure of the southeastern fields. The areas may be considered from north to south in the order: Hardinville, Birds, Sumner, and Vincennes.

Hardinville Quadrangle.[2]—"The structure of the Hardinville quadrangle is dominated by a major uplift of the formations into the La Salle anticline. In the southern half of the area the arch has the shape of an elongated dome, while in the northern portion it appears to have the form of an unusually broad terrace. The area of the greatest uplift is in the NE. ¼ sec. 30, T. 4 N., R. 12 W., near the southeast corner of the quadrangle, which shows maximum dip of 240 feet to the mile, while other portions of the area show an average dip of 50 to 75 feet to the mile or less than one degree.

"The structure of the Lawrence County portion of the quadrangle is shown by the use of contours drawn on the top of the Kirkwood[4] oil sand. It represents the northwestern extension of an elongated dome, having a length on the sheet of about eight miles and a width of about three miles. The general northwest dip of the strata is modified slightly by several minor irregularities which are most pronounced at the north end. The crest of the dome lies at the gas well in the NE. ¼ NE. ¼, sec. 30, T. 4 N., R. 12 W. North from this place the strata dip northward 330 feet in a distance of eight miles, or at an average rate of about 41 feet per mile. The outer flank of this dome-like fold is steep. The dip toward the west at the north end averages 170 feet

[1] Blatchley, R. S., The oil fields of Crawford and Lawrence counties: Ill. State Geol. Survey Bull. 22, 1913.

[2] Savage, T. E., and Blatchley, R. S., Description of the Sumner and Vincennes quadrangles: Unpublished manuscript in the files of the State Geological Survey.

Savage, T. E., Description of the Hardinville quadrangle: Unpublished manuscript in the files of the State Geological Survey.

[3] Rich, J. L., Oil and gas in the Birds quadrangle: Ill. State Geol. Survey Bull. 33, p. 105, 1916.

————Oil and gas in Vincennes quadrangle: Ill. State Geol. Survey Bull. 33, p. 147, 1916.

[4] See Plate III of present report.

per mile, while to the east it is 150 feet per mile. Near the crest of the dome the dip on the west flank averages about 205 feet per mile and on the east flank 183 feet per mile."

The structure as determined for the Crawford County portion of the quadrangle is based upon the Robinson sand, an upper sandstone member of the Pottsville formation and hence of Pennsylvanian age. Concerning the structure of the pre-Pennsylvanian rocks, Savage has nothing to say. It should be stated, however, that the northward dip below the valley of Embarrass River found in Lawrence County apparently terminates with an uplift in Crawford County, described by Savage as follows:

"The Robinson sand at the south end of the Crawford County field shows a marked dip toward the south, while the corresponding Bridgeport sand in the north part of Lawrence County dips quite strongly toward the north. There is thus formed across the anticline a wide basin or trough which lies chiefly below the zone of oil saturation and separates the oil field in the quadrangle into two distinct pools. The valley of the Embarrass in its eastward course across the quadrangle is over this basin or transverse syncline which probably determined the direction of flow of the river in this region."

It is, of course, unknown whether the structure of the Robinson sand in Crawford County parallels the structure of the pre-Pennsylvanian rocks, but the early rocks at least must have been affected by the deformation which raised the strata north of the Embarrass River trough.

Birds Quadrangle.—The Birds quadrangle lies to the east of the Hardinville quadrangle. The structure of the pre-Pennsylvanian rocks has been described by Rich [1] as follows:

"The available data indicate that a compartively sharp monocline, extending southeastward from the western edge of the map at about latitude 38° 50′ to near the center of the south line of the quadrangle, separates a low basin on the southwest, occupying all the southwestern corner of the quadrangle, from a relatively high, nearly flat area which occupies all of the quadrangle north and northeast of the monocline. This monocline is without doubt a continuation of the one recognized in the Hardinville quadrangle as bounding the Robinson oil pool on the west."

In the following two paragraphs of his report Dr. Rich summarizes the evidence of the structure as described and then adds:

"These figures indicate that north of the monocline, the Mississippian rocks lie approximately flat; but have a slight dip toward the east or southeast. As has already been shown, the data yielded by the wells which penetrate the Robinson sand in the Birds quadrangle prove that sand to lie essentially flat over the entire northern two-thirds of the area. Inasmuch as the surface rocks reveal only slight irregularities in structure, whereas the Mississippian rocks show differences in elevation of over 400 feet in the southern part of

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[1] Rich, J. L., Oil and gas in the Birds quadrangle: Ill. State Geol. Survey Bull. 33, p. 144, 1916.

the quadrangle, the existence of a great unconformity between the two is very clearly indicated.

"The absence, in the wells which reveal the 'Big Lime' at elevations of 400 feet or more above datum or recognizable representatives, of any but the basal rocks of the Chester group indicates that the major unconformity is between the top of the Mississippian series and the base of the Pennsylvanian series. This interpretation harmonizes with the evidence of unconformity at this horizon yielded by the fact that south of this area in the southern part of the Vincennes quadrangle, the thickness of the Chester beds occupying the interval between the 'Big Lime' and the base of the Pottsville increases, wedge-like, toward the south."

Sumner and Vincennes Quadrangles.—The structural geology of the Sumner and Vincennes quadrangles has been described by Savage and Blatchley.[1] Their account of the features of the structure of the Kirkwood sand, a Chester sandstone, is as follows:

"The structure of the oil fields in the Sumner and Vincennes quadrangles reveals chiefly the south half of a pronounced elongated dome or broad, flat area which resembles an extensive terrace, separated by a sharp monoclinal fold from a low basin occupying the southwestern portion of the area. The area of greatest uplift shows a maximum dip on the flanks of the La Salle anticline of 235 feet to the mile, while the dip southward from the dome is about 30 feet to the mile or less than one-half of one degree. The structure in both quadrangles as far as mapped, is shown by the use of contours on the top of the Kirkwood sand.

"The structure of the Kirkwood sand in the Sumner quadrangle represents the southeastern extension of an elongated dome, the northern part of which extends about 8 miles in a northwest direction into the Hardinville quadrangle. The dome in the Sumner area is about three miles long and 2½ miles wide. South of the dome the dip of the formations is arrested by a broad irregular flat which covers most of the oil fields of the Vincennes quadrangle, and its northern and northwest edges overlap the east side of the Sumner quadrangle. The strata dip to the west along the north boundary at the rate of about 225 feet per mile and east about 150 feet per mile. The dip from the crest of the dome southward toward the flat is about 65 feet per mile.

"The structure of the Vincennes quadrangle represents a broad flat crest of the La Salle anticline, which has the appearance of an extensive terrace. It is about 8 miles long and about 3¾ miles wide. The domelike structure in the adjoining quadrangle merges into a mild trough in secs. 3, 9, 10, 15, 21, and 22, T. 3 N., R. 12 W. Except for a mild dome about 60 feet high through sections 23, 26, 27, 34, and 35 of the same locality, the sand lies at a rather uniform level at about the 400-foot contour.

"To the west the rocks dip down steeply in a monoclinal fold extending southeastward from the western border of the quadrangle in sec. 21, T. 3 N., R. 12 W., and passing through sec. 20, T. 2 N., R. 11 W., under St. Francisville. Except near the western border of the quadrangle, where the lower limits of the fold are not known, the monocline flattens out within a distance of one

[1] Savage, T. E., and Blatchley, R. S., Op. cit.

to two miles and merges into a flat-lying terrace or basin which underlies the southern and southwestern parts of the quadrangle, and in which the rocks are about 400 feet lower than on the anticline at the south end of the main oil field. A minor arch in this low-lying area has permitted the accumulation of oil in the Allendale field, and a flat terrace at the base of the monocline seems to be the controlling factor in the St. Francisville field.

"The eastern flank of the principal anticline dips much less steeply than the western. From the crest there is an eastward dip of about 40 feet in a distance of two miles, beyond which the rocks flatten out and the average dip, as indicated by well records, does not exceed 10 feet per mile. On this flat eastern limb of the anticline, or more strictly, monocline, small local domes 20 to 60 feet in height have been discovered to be responsible for outlying pools such as that 1½ miles northwest of Billett and the Murphy pool. It is probable that a second monocline crosses the northeastern corner of the quadrangle in a northwest-southeast direction, entering from the Birds quadrangle, but there are not sufficient data to prove conclusively its existence."

The structure of the Kirkwood sandstone of the Vincennes quadrangle is also described by Rich: [1]

"As is clearly shown by the structure contours on the Kirkwood sand, the dominant structural feature of the quadrangle is the broad, low anticline, extending north and south through the area occupied by the main oil field a nearly flat terrace extending eastward from this anticline, and the low basin which occupies the southwestern portion of the quadrangle The anticline is clearly marked along a line extending from sec. 2, T. 2 N., R. 12 W., northward for about 6 miles to sec. 1, T. 3 N., R. 12 W. * * * At the north it appears to flatten out as the rocks dip northward toward the structural basin along Embarrass River. The anticline is connected along its northwestern side in secs. 15 and 16, 9 and 21, T. 3 N., R. 12 W., by a broad, nearly flat terrace with the sharper anticline which extends northward through the Sumner and Vincennes quadrangles from Bridgeport to Embarrass River. Along the western side of the anticline and terrace southward and southeastward, from the border of the quadrangle in sec. 21, T. 3 N., R. 12 W., the rocks on the western flank of the anticline dip deeply southwestward into the Illinois Basin. This steeply dipping flank of the anticline extends across the southern end of the oil field from sec. 10, T. 2 N., R. 12 W., toward St. Francisville, passing through the northern half of sec. 20, T. 2 N., R. 11 W., a short distance north of the town.

"It is probable that a comparatively sharp monocline crosses the northeastern corner of the quadrangle in a northwest-southeast direction from the middle of the north line, northeast of which the rocks are 300 to 400 feet higher than on the southwest The presence of this monocline is inferred from the logs of the deep wells in the Birds quadrangle to the north. The probability of the presence of this monocline is confirmed by the detailed log of a well on the Boonilletts farm, 4 miles north of Vincennes (not located on the map), in which the top of the Ste. Genevieve limestone is not less than 280 feet above datum.

"The eastern flank of the principal anticline dips much less steeply than the western. From the crest is an eastward dip of about 40 feet in a distance of

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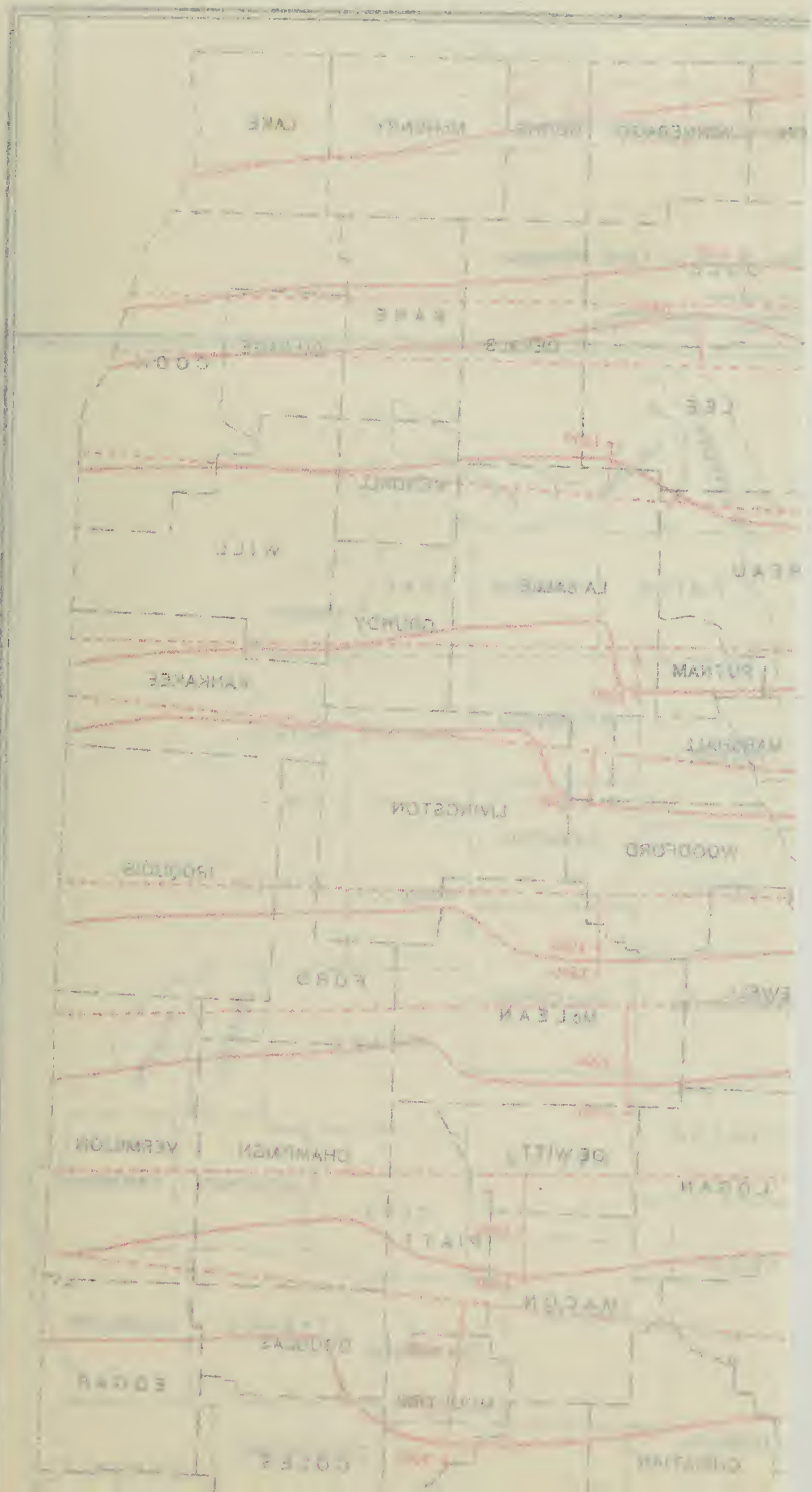
[1] Rich, J. L., Oil and gas in the Vincennes quadrangle: Ill. State Geological Survey Bull. 33, p. 172, 1916.



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two miles beyond which the rocks flatten out, and the average dip, as is indicated by the records of the wells farthest east, does not exceed 10 feet per mile. On this flat eastern limb of the anticline small local domes 20 to 60 feet in height have permitted the accumulation of oil at several localities forming the Billett, Hebert, and Murphy pools. Throughout this area the general conditions for the accumulation of oil are moderately favorable wherever small local domes occur. Such domes are likely to be of small area, and their presence can be determined only by the drill."

The structural features of the La Salle anticline in the main oil field are summarized in the map already presented as Plate III. On it are shown the position of the various oil pools along the La Salle anticline in Crawford and Lawrence counties, and the crescentic sweeping curves of the monoclines and troughs that swing off to the southeast at various places in the oil fields are indicated by the contours or the trend of the producing areas. Some idea of the southward pitch of the older rocks along the anticline may be obtained by a comparison of figures indicating the depth of these formations at the different drill holes. The southward pitch of the strata from Mahomet may also be observed by an inspection of the accompanying structure section sheet (Plate IV) showing graphically several records of drill holes between Mahomet and Vincennes. The extent of the unconformity between Pennsylvanian and pre-Pennsylvanian strata is evident from the great increase southward in the interval between No. 6 coal and the Mississippian limestone—the "Big Lime"—as shown by the figures on the map and by the structure sections.

PROFILES OF THE SURFACE OF THE ST. PETER SANDSTONE

Supplementary to the data presented on the structure map numerous profiles based upon drilling data have been constructed across the State to show the structure of the St. Peter sandstone (see Plate V). These are twelve in number and are so constructed as to show the surface of the St. Peter sandstone and its relation to sea level. The straight line at the top or bottom of the profiles represents sea level and is drawn approximately across the line of the section. The profiles are serviceable in emphasizing some of the points previously mentioned in the interpretation of the structure map. These are: (1) the broad character of the structure in northern Illinois; (2) the sharpness of the fold in La Salle County; (3) the apparent nearly total obliteration of the deformation in Livingston County; and (4) the relatively steep eastward limb of the fold in Champaign County.

CHAPTER IV—DESCRIPTION OF THE STRUCTURE OF THE PENNSYLVANIAN STRATA

Preliminary Statement

Just as in the case of the older rocks the structure of the Pennsylvanian system is better known in some regions than in others. In the La Salle region, for instance, the La Salle coal can be followed the entire length of the west limb of the anticline from the crest to the trough, and exposures of other beds are common along the anticline. Farther south, however, and toward the west the structures are not well exposed, and drilling even though common, as in the oil fields, is not of the character that permits of the ready identification of the thin beds common to the "Coal Measures". Identification of thin limestones and coals, and their correlation from drill hole to drill hole, is possible with practical certainty of correctness where the drilling is done with a diamond drill and the core correctly and carefully described; but where the drilling is done by the churn drill, which is commonly used in sinking an oil or gas prospect, a detailed record showing the correct thickness and character of the successive beds is practically impossible to obtain and is not commonly attempted. Where the drilling chips can be examined by a geologist, much more reliable records can be assembled than are commonly furnished by the driller, but the geologist is not often given the opportunity of making the examinations. The Survey has hundreds of excellent records of drill holes in the coal field west of the anticline, but to the east, except in Vermilion County most of the information in regard to the "Coal Measures" is based upon churn-drill records, and in most of these only the oil or gas sand is noted.

Areal Geology

As with the older rocks the distribution of the Pennsylvanian system as a whole without respect to the subdivisions throws considerable light upon the position and the form of the fold. In the La Salle region, for instance, the boundary between the Pennsylvanian rocks and the older formations is known to follow the line of folding from northeast Bureau County near La Moille to the south bluff of the Illinois southwest of Utica. Thence the boundary swings around the blunt end of the anticline which terminates in La Salle County as far as the northeast corner of Grundy County. It does not seem improbable that the "Coal Measures" may now or did once extend into the Pawpaw-Aurora syncline. The

Pennsylvanian strata seem to be persistent over the crest of the fold in southern La Salle and in Livingston counties, but in Champaign and Douglas counties there apparently is a narrow area along the crest of the anticline where the Pennsylvanian rocks, at least such are coal bearing, have been entirely removed. Wells at Mahomet, Champaign, Pesotum, and Tuscola are similar in reporting the absence of Pennsylvanian strata. The drift in this region is very thick, amounting in places to 300 feet. Even were only about 300 feet of Pennsylvanian strata present this far south in the coal basin, it would represent a notable thinning of the measures as compared with the thickness existing in the troughs to the east and west, 896 feet of drift and "Coal Measures" being found, for instance, at Heyworth, in McLean County which lies several miles north in the trough of the Illinois basin.

The areal geology of the Pennsylvanian system as a whole indicates a general axis of elevation along the line of the La Salle anticline as mapped for the St. Peter sandstone.

Structure of Pennsylvanian Rocks in the La Salle Region as Revealed by Field Investigations of Outcrops and by Mine Examination

Field observation of Pennsylvanian structure both above and below ground is limited entirely to the La Salle region. There have been some investigations of the structure of the exposed rocks in Crawford and Lawrence counties along the line of the anticline, but these investigations discovered no significant irregularities in the structure of the surface rocks.

UNDERGROUND STRUCTURE

NO. 2 COAL

Two mines in the La Salle field are operating or have operated in No. 2 or "Third Vein" coal on or contiguous to the fold. One of these, the Black Hollow mine of the Illinois Zinc Company, located near the center of sec. 30, T. 33 N., R. 2 E., has driven its operations from well up on the flank of the fold above the outcrop down to the trough. The other mine, the old Rockwell shaft of the La Salle County Carbon Coal Company, located in sec. 14, T. 33 N., R. 1 E., worked for some distance up the inclination from the west but finally ceased operations in that direction because of difficulties encountered.

Structure of No. 2 coal in Black Hollow mine.—Observations on the dip in the Black Hollow mine have been taken constantly under the direction of Mr. J. A. Ede, mining engineer in charge, so that the structure of the coal bed is known. The mine is a slope or drift mine entering the

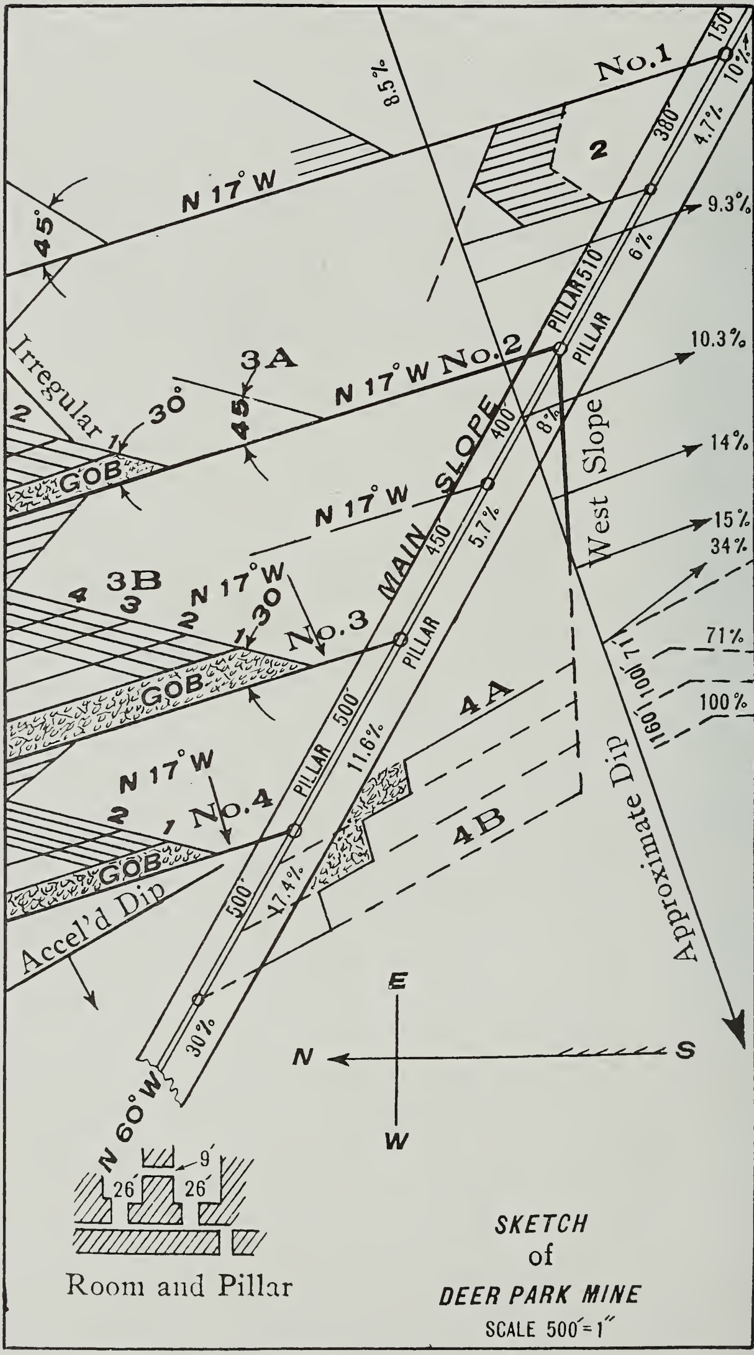


Fig. 12.—Dip and strike in Black Hollow (Deer Park) mine. From drawing furnished by Mr. J. A. Ede, Mining Engineer.

seam part way down the west limb of the anticline about 25 feet above Vermilion River. The main entry is driven on a N. 60° W. course quartering the dip of the seam at an angle of 47°, the strike accordingly being N. 17° to 19° W. The coal at the mine entrance has a dip of 10 to 15 per cent (9°); in the next 200 feet it increases to 34 per cent (20°); in the next 100 feet to 71 per cent (37°); and in the next 250 feet to 100 per cent (45°). Shortly below this the foot of the incline was reached, but not until a dip of between 50 and 55 degrees was encountered. The structure as indicated above is shown graphically in the accompanying sketch (fig. 12) reproduced from a drawing prepared under the direction of Mr. Ede.

In the description of the structure of the St. Peter sandstone in the vicinity of Deer Park, mention was made of a sudden increase in the dip of the sandstone along a certain line whereby a distinct elbow or angle was produced in the surface of the rock. The coal overlying the position of this change in dip does not appear to change its inclination. About 1,000 to 2,000 feet west, however, in the Black Hollow mine the dip gradually increases from 6° to 10°. Then the inclination increases greatly, as described in the preceding paragraph, producing a sudden change in the dip from about 10° to about 20° with a constantly increasing dip toward the bottom of the trough. At one position another sudden change was noted, involving an increase from about 40° to 50°, marked by a distinct angle or elbow in the surface of the fire clay underlying the coal. At the foot of the slope there is a sudden flattening out of the strata without much further inclination.

Other relationships in this mine to which special attention needs to be directed concern the variations in the direction of strike and dip. The coal in the upper part of the west limb down to the line of increased dip, which is called the "line of accelerated dip" by the engineer in charge of the mine, is inclined 10° or less and the strike is approximately N. 19° W. The line of increased dip bears more to the west, its strike being about N. 30° W., and the strata down the dip from this line are inclined about at right angles to this bearing, with increasing rate of dip up to about 50°. The various relationships of dip, strike, increased dip, etc., are shown in figure 12 and Plate VI.

Structure of No. 2 coal in Rockwell mine.—The abandoned shaft of the Rockwell mine of the La Salle County Carbon Coal Co. is located near the center of the NW. ¼ SE. ¼, sec. 14, T. 33 N., R. 1 E., about ½-mile east of Little Vermilion River along the bluff line of Illinois Valley. The altitude of the coal at the bottom of the shaft is about 110 feet above sea level. On the accompanying sketch map (Pl. VII) the structure of the coal on the east side of the mine approaching the fold is shown by con-

tour lines at five-foot intervals, an arbitrary elevation of 100 being assumed as the altitude of the coal at the base of the shaft. The coal lies nearly horizontal for a distance of 2,600 feet east, beyond which there is a conspicuous rise. From the difference existing between the altitude of the coal in the mine workings and as determined in a drill hole about 500 feet east of the workings it is evident that as in the Black Hollow mine the coal is more steeply inclined near the foot of the west side of the anticline than it is higher up on the slope. In the mine the greatest change in altitude as shown on the map is 7 feet in a distance of about 30 feet. This corresponds to a dip of 12° to 13°. This rate of slope apparently continues some distance east, for between a point immediately below the triangulation station shown on the map and bore hole No. 6, a distance of about 500 feet, the coal rises about 140 feet, a 13° dip being the average inclination between the two points. Between the drill hole (No. 6) and the outcrop of the coal at Split Rock there is a decrease in the average rate of dip. The distance is about 1,400 feet and the difference in altitude about 200 feet, which is equivalent to a 14 per cent or 8° dip. The dip of the sandstone layer a short distance below No. 2 coal at Split Rock is about 8½°, and it is possible that the dip of the coal is still less.

STRUCTURE OF EXPOSED ROCK

The structure of exposed Pennsylvanian formations is best shown by certain readily identified or conspicuous strata outcropping along the valleys of the Illinois and Little and Big Vermilion rivers. Of these strata No. 2 coal and the La Salle limestone are the most important, but the other coal beds and limestones are also useful in determining the structure. The outcropping rocks are exposed along the west flank of the fold, but no single stratum is exposed from the trough to the crest of the anticline. Those strata like No. 2 coal which are exposed from the top of the fold to a position part way down the slope are below the surface on the lower part of the slope, whereas strata like the La Salle limestone, which is exposed in the trough of the fold and a short distance up the slope, have been eroded over the crest. Accordingly, for a profile of the structure it is necessary to obtain underground data such as have been introduced.

NO. 2 COAL

Description of structure.—No. 2 coal is exposed almost continually along the west slope beginning about 125 feet below its highest level along the axis of the fold. As the total difference in altitude of the coal between the crest and the trough of the fold is about 500 feet, the exposures are available only about ¼-way down the slope. Eastward, however, from the axis of the deformation on the east flank there are exposures of the

coal to about 1 mile east of the mouth of Fox River. On Vermilion River and its tributaries the exposures are mainly near the top of the west slope, and at Lowell the coal is exposed practically at the crest of the fold. Along Little Vermilion River the relationships are about the same as along Big Vermilion, except that the rocks over the crest of the fold are more rarely exposed.

The structural relation of the Pennsylvanian and pre-Pennsylvanian strata is of some interest. The No. 2 coal is probably nowhere entirely parallel with the older strata, but the structure closely approximates parallelism in certain positions across the fold. From where the older rocks suddenly incline more steeply to the west, a position which has been designated as the "line of increased dip" of the pre-Pennsylvanian strata, upward along the slope to the crest of the anticline the Pennsylvanian and pre-Pennsylvanian strata are nearly parallel; not entirely so, however, as the lower rocks pitch southward along the axis of the fold more steeply than do the "Coal Measures." East of the axis, likewise, the coal and the pre-Pennsylvanian strata are nearly parallel, but there is a slightly steeper eastward inclination of the lower beds toward the trough of a broad syncline the axis of which extends south from near Seneca. East of this axis the older rocks rise again more rapidly than the coal. Here and there irregularities such as the syncline in the sandstone at Covel Creek are indicative of the structural unconformity between the Pennsylvanian and pre-Pennsylvanian rocks on the east side of the crest of the anticline.

A somewhat different relationship between the structure of the Pennsylvanian strata and the underlying formation along the crest of the fold appears to exist at Lowell than was noted farther north. At Deer Park, for instance, the coal and the St. Peter sandstone are very nearly parallel across the axis of the deformation and for a distance down either side. At Lowell on the other hand, the Galena-Platteville, which underlies the Pennsylvanian, dips at an increasing rate down stream from some distance above the bridge, the coal being nearly horizontal or affected only by the southward pitch of the rocks, dipping slightly in that direction.

Development of structure.—From the line of increased dip of the pre-Pennsylvanian strata down to the lower limit of exposure the structural unconformity between the Pennsylvanian strata and the lower strata is very evident, but above this line it is not so, all formations being more nearly parallel. There seems to be no change in the rate of dip of the coal as it crosses the line of increased dip of the pre-Pennsylvanian rocks, as observed at Deer Park, near Black Hollow, at Split Rock, and at places along the Little Vermilion. It is apparent, therefore, that de-

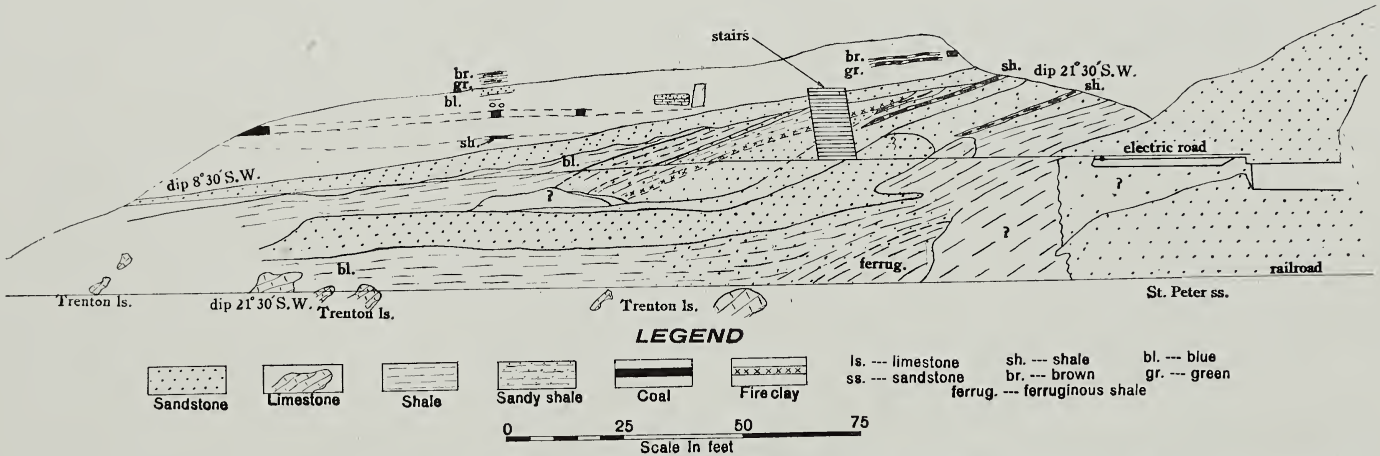
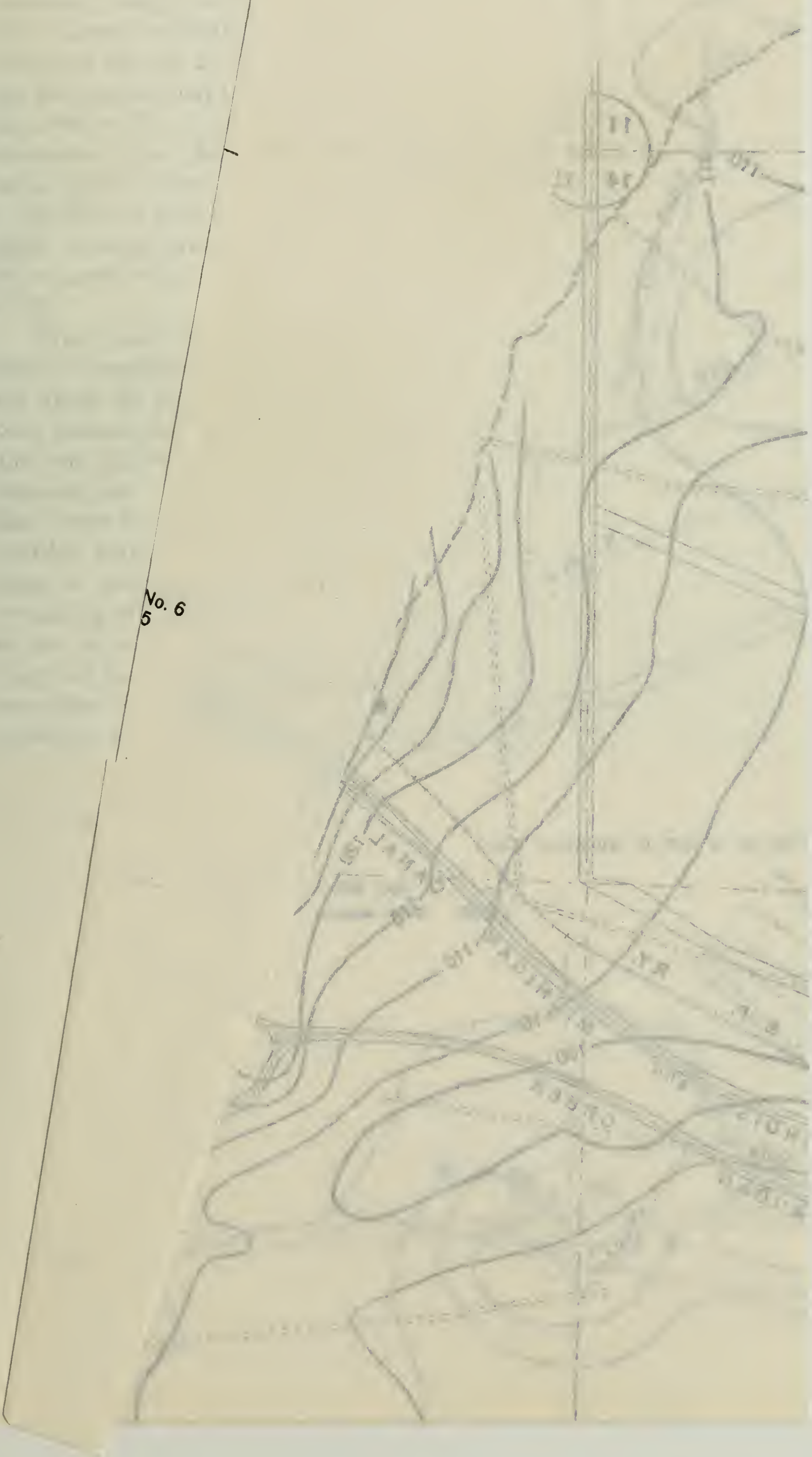


FIG. 13.—Structural and stratigraphic relationships at Split Rock. The photograph reproduced as Figure 11 was made from a point near the words "electric road" on the above diagram, looking in the general direction of the stairs.

ILLINOIS STAT TIN NO. 36, PLATE VII



formation along this line took place prior to the deposition of No. 2 coal. Certain structural and stratigraphic relationships existing at Split Rock near the cen. N. ½ sec. 13, T. 33 N., R. 1 E., indicate that some of this deformation may have taken place in Pennsylvanian time prior to the deposition of No. 2 coal. The accompanying sketch (fig. 13) shows the conditions at this place. An unconformity is shown within the Pennsylvanian system below a continuous ledge of sandstone which underlies by a few feet the position of No. 2 coal. The sketch also shows the commonly existing structural relationships between No. 2 coal and the St. Peter sandstone or Platteville limestone west of the line of increased rate of dip.

From these various relationships it appears that the deformation of the pre-Pennsylvanian strata took place prior to the deposition of No. 2 coal along the line of the increased dip, and the relationships at Split Rock indicate that some of this movement may have been during Pottsville time, all Pennsylvanian strata below No. 2 coal being regarded as of Pottsville age. There had also been regional southward tilting of the older strata in pre-Pennsylvanian time. Structural conditions previously described indicate that after deposition of No. 2 coal there was elevation along an anticlinal axis several hundred feet east of the line of increased dip of the older strata. As a result, the strata on the west side of the axis were inclined not over 8° to 10° westward, the dip to the east being still less (see fig. 14). If to the above is added the information concerning No. 2 coal obtained in the mines a third folding took place possibly at a still later time west of the line of increased dip of the pre-Pennsylvanian strata. This folding produced the belt of steeply dipping strata discovered in the mines. The various structural relationships as described are shown graphically in order of sequence in the accompanying sketch (fig. 14).

STRUCTURE OF PENNSYLVANIAN STRATA BETWEEN NO. 2 COAL AND THE LA SALLE LIMESTONE

The structure of outcropping Pennsylvanian rocks above No. 2 coal and below the La Salle limestone is not very accurately determinable. The reason for this lies in the lithologic character of the strata; most of the members of this part of the section consist of soft shales or massive structureless sandstones. There are two coal beds and a few thin limestones upon which, locally, dip and strike can be satisfactorily measured; but the regional nature of their deformation is not determinable either because of lack of continuity, or of failure of exposure, or of impossibility of correct correlation from outcrop to outcrop.

So far as observed these intermediate strata are not known to dip as steeply as No. 2 coal in the Black Hollow mine. Gray shales about

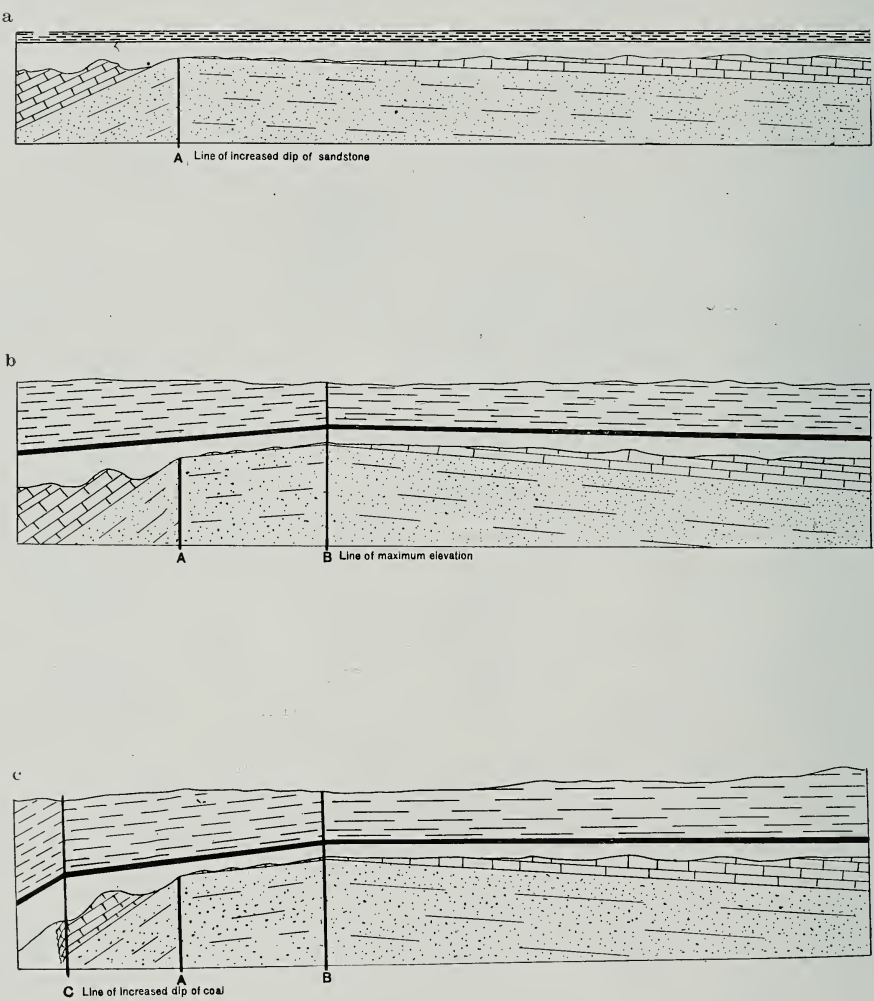


FIG. 14.—Diagrammatic sketches showing the succession of events in the LaSalle region.

a. Showing the older rocks folded prior to the deposition of peat which formed No. 2 coal.

b. No. 2 coal and older rocks folded along the axis lying east of the original line of deformation.

c. No. 2 coal and older rocks folded along a line west of the two other lines of deformation.

midway of the Pennsylvanian section are exposed in the vicinity of Split Rock where they have a dip of about 20°; the same beds on the south side of the Illinois in approximately the same position relative to the axis of the fold dip only about 10°. Other beds upturned by the fold and exposed in gullies between Split Rock and the outcropping La Salle limestone (sec. 13, T. 33 N., R. 1 E.) are inclined as much as 14° to 20°. Strata along the Little Vermilion near the mouth of Tomahawk Creek dip as much as 13°. One of the intermediate coal beds, known locally as the "Second Vein", which is exposed in the bluff of the Vermilion south of the suspension bridge at Deer Park, dips upstream about 12° to 15°, declining from an altitude of 560 feet to the level of the river (460 feet) in a distance of about 1,600 feet, a slope which is equivalent to an average dip of about 3½°. The dip is probably greater than this average in places, especially toward the west.

Such data as are available concerning these intermediate strata seem to indicate that the steepness of inclination increases somewhat down the dip, but no evidence has been found of a line beyond which there is a marked increase in the rate of dip. Apparently such increase affects only strata below the level of outcrop, that is below an altitude of about 480 feet. The structural relations are not absolutely clear but they point to unconformable relations between the different members involved. This probability is further enhanced by the thinning of the system as it rises over the anticline, indicated by the decrease in interval between No. 2 coal and No. 5 coal ("Second Vein"). This interval in the basin west of the fold is about 180 feet,[1] but along Vermilion River near Deer Park the two coals outcrop in the same bluff with a possible interval not greater than 100 feet, and probably not more than 80 feet. This decrease in interval is described at greater length in an ensuing paragraph.

STRUCTURE OF THE LA SALLE LIMESTONE

Further data in regard to the detailed structure of the Pennsylvanian rocks in the La Salle region are afforded by observations at outcrops and by drilling data that concern the altitude of the La Salle limestone. This member of the Pennsylvanian system is a conspicuous cliff-forming limestone along Illinois and the two Vermilion rivers, found in typical expression only parallel to the anticline along the west limb of the fold. The value of this member in these studies lies in its continuity of exposure and in the fact that the limestone strata and associated beds afford satisfactory planes upon which to make structural measurements. Its distribution is indicated on the accompanying map (fig. 15) and the

[1] Ill. Coal Mining Investigations Bull. 10, pp. 81-83, 1915.

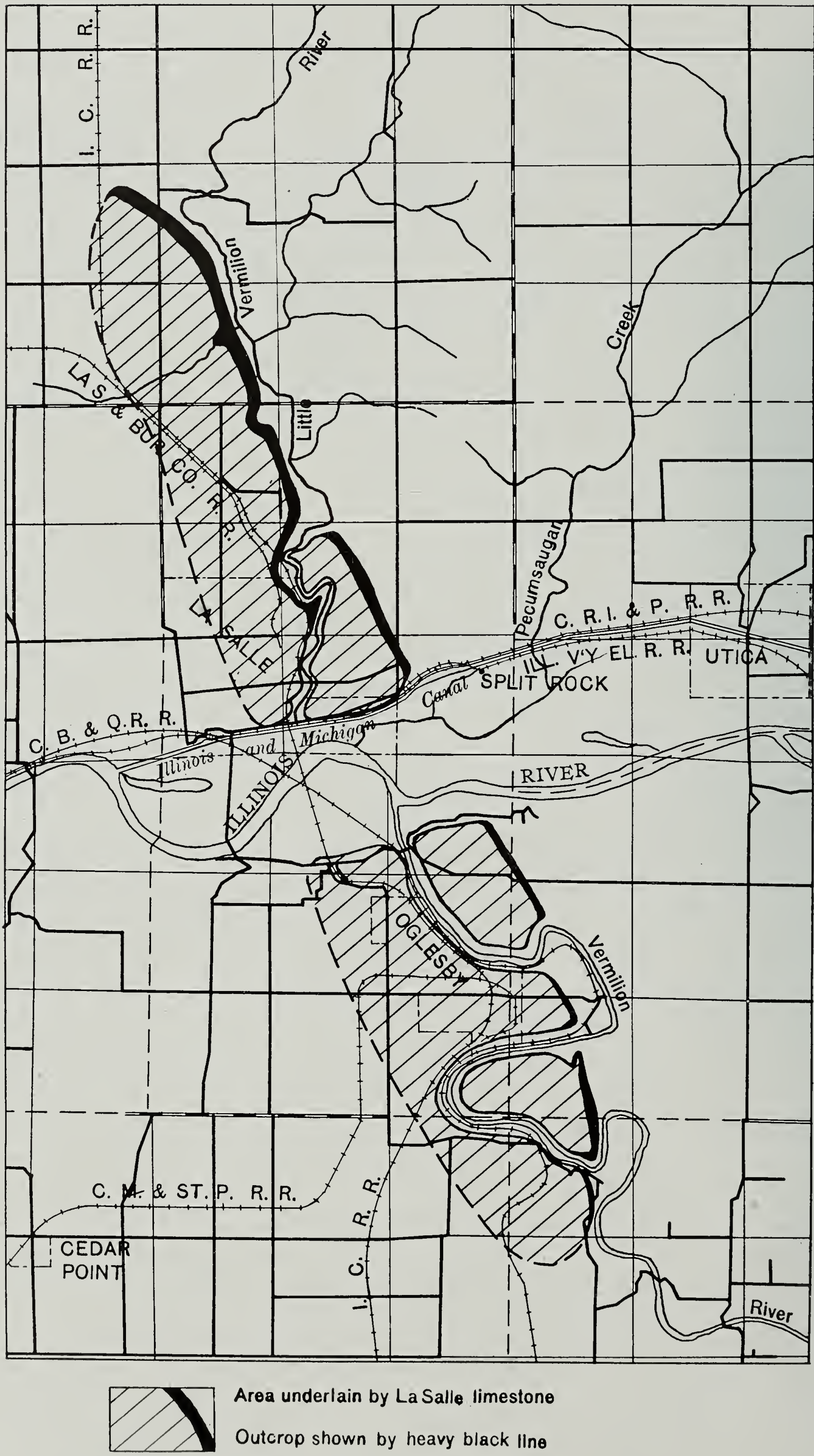


FIG. 15.—Map of the La Salle region showing the distribution of the La Salle limestone. Scale, 1½ miles to the inch.

parallelism to the anticline is apparent. Stratigraphically this member lies about 400 feet above No. 2 coal. Underlying the limestone is a black fissile shale which is readily recognizable and which affords an excellent structure datum.

Because of outcrops or drilling the structure of the La Salle limestone is especially demonstrable in three localities: (1) From La Salle east on the outcrop along the north bluff of the Illinois; (2) along Vermilion River east from the quarry of the Chicago Portland Cement Co.; and (3) along Vermilion River east from the plant operated by the Marquette Portland Cement Co. At the last two localities the results of drilling or leveling by the cement companies have been made available. In all of the areas the structure is very similar.

(1) The limestone is horizontal at La Salle and across the Little Vermilion in the quarry of the La Salle (formerly German-American) Portland Cement Co. At this quarry the altitude of the base of the limestone or the top of the black slate is 490 feet above sea level. One mile east of the Little Vermilion is an old quarry along the Illinois bluff and the electric road, where the altitude of the same horizon is about 505 feet. The strata rise from this point eastward, outcropping finally as a ridge extending N. 27° W., toward the valley of the Little Vermilion from the Illinois bluff at a point about 1,000 feet northeast of the quarry. The altitude of the base of the limestone along the ridge at the outcrop is about 580 feet, and the dip, measured along strata exposed in an abandoned quarry at the crest of the ridge is about 15°, N. 35° W., the strike apparently being locally slightly more to the west than the general bearing of the ridge as a physiographic feature.

(2) Along Vermilion River at the quarry of the Chicago Portland Cement Company somewhat similar data are obtainable. The altitude of the base of the limestone in this quarry is about 507 feet above sea level at a point opposite the mills. Drillings along a line running east from the quarry (Pl. VI) indicate that the strata dip west from the outcrop along the bluff of the Vermilion at an angle of about 13°, a dip which produces a decrease in altitude of about 30 feet in 150 feet of distance. For the next 950 feet the rocks decline only 12 to 15 feet, the average dip being about ½°. In the next 400 feet the limestone has an average dip of about 4° producing a difference of altitude of about 28 feet; thence west to the river the strata are essentially horizontal. This structure is apparently very much the same as that along the Illinois as described above, and is similar to that observed at other places along the Illinois and Little and Big Vermilion rivers where the strata rise on the flank of the fold.

(3) Information concerning the structure of the limestone has also been contributed by the Marquette Portland Cement Co., based upon

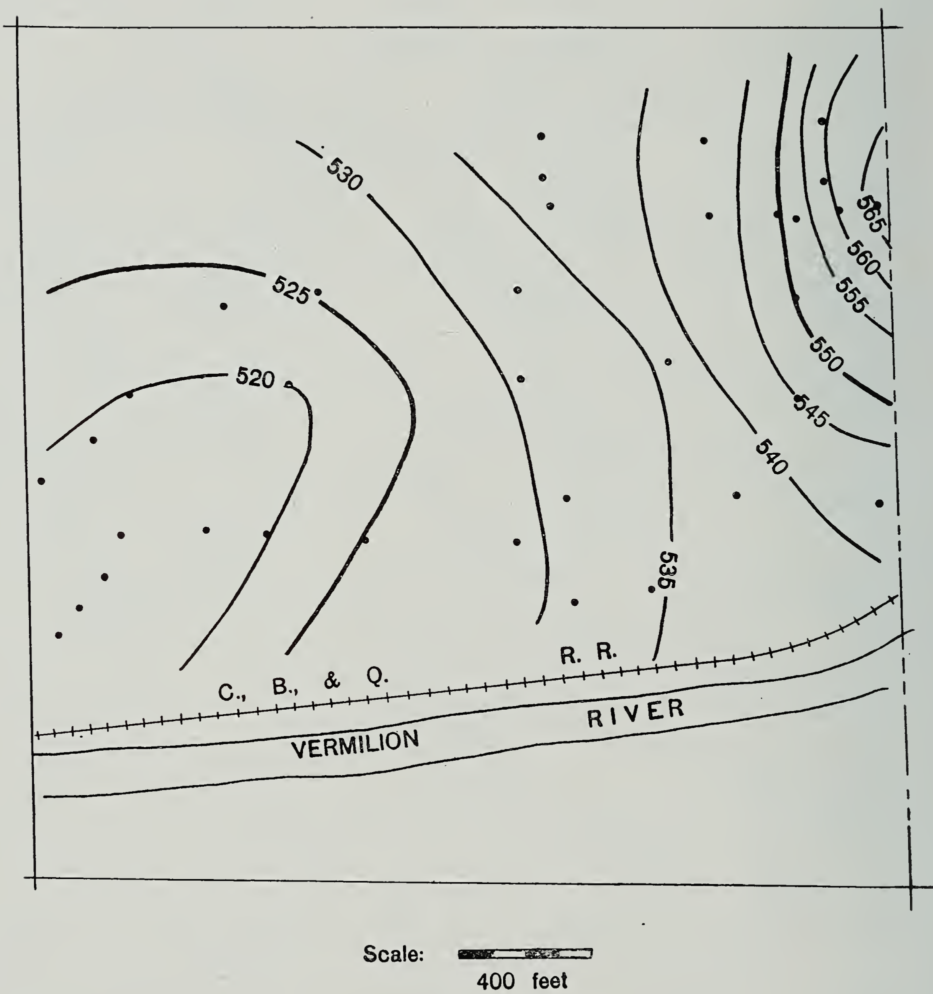


FIG. 16.—Structure of the La Salle limestone in the NW. ¼ sec. 31, T. 33 N., R. 1 E.

levels in their mine. Observations on the altitude of a bed of shale 7 feet from the base of the limestone have been made at a number of places in the NW. ¼ sec. 31, T. 33 N., R. 2 E. Here, as in similar places near the fold, it is evident that the deformation affects the strata suddenly, the rock rising on the west limb of the anticline from an approximately horizontal position. The accompanying sketch map (fig. 16) is a structure map of the La Salle limestone based upon the altitude of the 7-foot shale at various points indicated by dots. Near the west line of the section the limestone has an altitude of 517 to 521 feet; near the northeast corner of the ¼ section the altitude is 560.9 feet, the total rise being 40 feet. Of this rise 30 feet is in the last 1,150 feet, 20 feet in the last 400 feet, and 10 feet in the last 130 feet,, which latter rise is about an 8 per cent or 4° dip. The rocks dip somewhat southward and the main anticline as determined by this structure map has a bearing of between 12° and 20° west of north, the exact direction being indeterminable from the map. It will be remembered that this is about the bearing of the No. 2 coal in the Black Hollow mine above the line of increased rate of dip.

Unfortunately for the purposes of this study, comparison of the structure of the La Salle limestone with that of the lower strata, especially No. 2 coal is possible only for the lower 1,000 feet of the west limb of the fold. The conclusions reached on the basis of these data might be more clearly substantiated were the Pennsylvanian rocks not so largely removed across the crest of the fold, yet it is believed that such conclusions do not overreach the evidence that is at hand.

The two significant facts about the structure of the limestone are: (1) Its apparent unconformity with the structure of the coal and (2) the apparent parallelism of the strike of the limestone with the bearing of the line of increased dip existing in Black Hollow mine and probably present in Rockwell mine. The amount of divergence in dip between the limestone and the coal is probably as much as 25° and possibly more. In one place only along the fold is the limestone known to dip more than 20°, a dip of about 24° having been measured along Little Vermilion River about 3 miles north of La Salle. Elsewhere the dip is rarely more than 15°. If the folding of the limestone, a deformation which would of course affect underlying strata, took place later than the folding of the coal along the axis now marking the position of maximum elevation, there would be produced a belt of increased dip in the coal such as has been observed in Black Hollow mine. The apparent parallelism of this line of increased dip with the strike of the limestone is a structural relation which seems to substantiate this interpretation of the structure.

If there were two periods of deformation, as suggested, in Pennsylvanian time, one after the deposition of No. 2 coal and before the

deposition of the La Salle limestone there should be some stratigraphic evidence that such was the case. This is not altogether lacking in the thinning of the formation against and over the fold. The greatest known interval between No. 2 and No. 5 coal near Deer Park is about 100 feet, as has already been stated. The same strata occupy 180 to 200 feet west of the fold. Along Vermilion River in the NW. ¼ NW. ¼, sec. 8, T. 32 N., R. 2 E., No. 5, or possibly No. 7, coal is present along the north side of the river probably not over 75 feet above No. 2 coal. The upper coal seems to be about horizontal. The coal with its floor clay overlies a massive sandstone below which there is a definite erosion unconformity. In the Streator region, which is east of the crest of the fold, the interval between No. 2 coal and No. 7 coal varies from 115 to 40 feet. This is 80 to 100 feet less than the interval between the same coals in the southern part of La Salle County west of the anticline. No. 5 coal which lies about 50 feet below No. 7 coal in the region west of the anticline is not developed in the Streator region. At Marseilles the interval between the upper and lower coals is about 125 feet.

Although, possibly, evidences of thinning of the Pennsylvanian strata are not especially convincing at Deer Park, farther south where the southward pitch of the fold causes higher members of the Pennsylvanian system to extend over the crest of the deformation, there seem to be definite indications of decrease in interval between coal beds. This decrease amounts to ⅓ or more of the interval prevailing west of the anticline. That a structural unconformity exists within the Pennsylvanian system therefore seems probable.

That the latest folding began during or a short time before the deposition of the La Salle limestone is possibly to be concluded in view of the position relative to the fold of the typical lithologic facies of the limestone. Where typically developed the rock is calcareous limestone containing very little magnesium, but considerable argillaceous material. It is fossiliferous in certain benches which are especially shaly. Some of the layers are semicrystalline and crinoidal, but the rest of the rock is nodular with a brecciated structure. It is composed of many nodules the size of a walnut or even smaller, closely embedded in an argillaceous matrix, which originally might have been limy mud. Each nodule is composed of very pure, smooth-textured, very fine limestone. Such nodules are not commonly, if at all, fossiliferous. The character of the nodules suggests a chemical origin for this portion of the rock, in which case the rock was probably deposited in shallow actively agitated water where evaporation was effective.

Where typically developed the limestone is distributed in a narrow belt barely one mile in width at the foot of the west side of the anticline.

Westward it becomes shaly or else very earthy and siliceous, losing its typical aspect entirely.

In explanation of the phenomena described, the theory is advanced that during the deposition of the limestone slight uplift was proceeding thereby producing shallow water and reef conditions which would be favorable, with suitable climatic conditions prevailing, for the development of concentrated solutions from which the lime could be deposited. Agitation of the water by warm winds would favor evaporation and the currents would tend to roll about on the sea floor the limy nodules formed by precipitation, eventually burying them in a limy mud. Some evidence of a warm climate is found in the red shales that immediately overlie the La Salle limestone.

Regional Structure of Pennsylvanian Strata

PRELIMINARY STATEMENT

The structure of the Pennsylvanian system lengthwise of the La Salle anticline can be determined only by the study of drill records. The area of exposure of rocks affected by the deformation in the La Salle region does not extend for more than 10 miles along the west limb and crest of the fold, and no other similar area exists. Between La Salle and Clark County the drilling is sparsely distributed, so that only a general idea of the structure can be obtained. In the oil fields of Clark, Crawford, and Lawrence counties more satisfactory information is available, but even these data largely concern the east flank of the anticline. From such data as are at hand a structure map of the Pennsylvanian system (Pl. VIII) has been prepared using a 100-foot contour interval and No. 2 coal as the structure datum.

The structure of No. 2 coal in the Longwall field of the northern part of the coal basin has been previously mapped and the map appears in Bulletin 10 of the Illinois Coal Mining Investigations.[1] The data included in the earlier map have been incorporated in the structure map of No. 2 coal accompanying this report. The structure maps of the southern part of the coal basin presented in other bulletins of the Illinois Coal Mining Investigations are, except for the bulletin which concerns the coal resources of Jackson County, based upon the altitude of No. 6 coal. These contours are adapted in their form and position to the purposes of the present map by assuming a uniform interval of 300 feet between No. 2 and No. 6 coals. This figure is generally correct within about 50 feet, especially toward the central part of the coal basin, the portion with which this report is particularly concerned, and an error of this order will not, it is believed, vitiate the conclusions based upon the structure as deline-

[1] Cady, G. H., Coal resources of District I (Longwall): Ill. Coal Mining Investigations Bull. 10, Pl. I, 1915.

ated. Areas included in the maps presented in the various coal reports already published are indicated on the structure map, and the contours in these areas are drawn, for the most part, with full lines. The contours within the area not previously mapped are broken lines, the structure as represented being based upon less satisfactory and generally more scattered data than are available within the areas already mapped.

The structure map shows the location of drill holes and a few mines outside the area already studied, data concerning which were used in the construction of the structure map. The records of most of these shafts and drill holes have previously been published so that the data may be readily verified. The following table gives the reference to the published records, and also shows the estimated or determined altitude of the mouth of the well or of the shaft entrance. The location of the wells in Clark, Crawford, and Lawrence counties is indicated with greater precision in Plate III.

TABLE 31.—*Index of published records of drillings and coal shafts in the eastern part of the Illinois coal basin*

County	Town or farm name and well number	Location Sec. T. R.	Altitude above sea level	Reference: Geol. Survey of Illinois Vol. Page	Reference: Ill. State Geol. Survey Bull.	Page
			Feet			
Champaign,...	Ivesdale.........	1½ miles S.	750[a]	...	16	122
	Tolono...........	...	730[a]	...	8	312
					16	123
Clark.........	Young No. 1.....	17 11N 14W	...	...	2	43
	Young No. ?.....	17?11N 14W	...	...	24	91
	Briscoe No. 1....	29 11N 14W	...	...	2	45
	Shover No. 1.....	1 10N 14W	600[a]	...	24	93
Coles..........	Charleston.......	...	...	VII 26	..	..
	Mattoon..........	...	...	VII 20	..	..
				VIII 36	..	..
Crawford.....	Highsmith.......	14 7N 12W	...	...	24	113
	Wilson No. 21.....	17 7N 12W	490[a]	...	22	49
					24	102
	Jones, D. C........	22 7N 12W	...	...	2	62
	Drake No. 23.....	9 7N 13W	490[a]	...	22	47
					24	100
	Curtis No. 8......	11 7N 14W	475[a]	...	22	44
					24	104
	Schiltz No. 7....	7 6N 13W	485[a]	...	22	33
					24	107

TABLE 31.—*Continued*

County	Town or farm name and well number	Location Sec.	T.	R.	Altitude above sea level	Reference: Geol. Survey of Illinois Vol.	Page	Ill. State Geol. Survey Bull.	Page
					Feet				
	Edwards No. 15	7	6N	13W	485[a]	...		22	35
								24	109
	Newlin	27	6N	13W	498	...		22	38
								24	114
	Cochran No. 9	21	5N	11W	...	...		22	51
								24	116
	Parker, W. No. 7	3	5N	12W	555	...		33	111
	Siler No. 4	5	5N	12W	495[a]	...		22	41
								24	96
DeWitt	Farmer City		...		...	VII	16	..	..
Douglas	Tuscola		...		...	VIII	25	..	..
Edgar	Hildreth	4	16N	13W	750[a]	...		16	124
Effingham	Edgewood		...		...	VII	33	..	..
	Effingham		...		...	VIII	55	..	..
Hamilton	Delafield	34	4S	5E	450[a]	...		16	93
	Elm Grove	27	4S	6E	410[a]	...		16	94
Lawrence	Wood No. 13	20	4N	12W	430	...		22	79
	Robinson	25	4N	12W	415	...		33	112
	Willey No. 4	30	4N	12W	517	...		22	76
	Pepple No. 7	30	4N	12W	430	...		22	77
	Boyd No. 11	30	4N	12W	452	...		22	119
	McCleave No. 4	31	4N	12W	520	...		22	71
								24	118
	Perkins No. 17	32	4N	12W	479	...		22	121
	Cummings No 12	6	3N	12W	516	...		22	70
	Gray No. 2	7	3N	12W	495	...		22	63
								24	123
	McPherson No. 3	11	3N	12W	429	...		22	67
	Tracy Heirs No. 1	12	3N	12W	455	...		22	134
	McPherson No. 4	12	3N	12W	425	...		22	68
	N. Tracy No. 2	13	3N	12W	425[a]	...		33	154
	Kirkwood No. 7	14	3N	12W	435	...		22	69
	Snyder No. 7	25	3N	12W	495	...		22	55
								24	129
	Seed No. 3	29	3N	12W	513	...		22	61
	Seed No. 1	29	3N	12W	476	...		22	132
	McOrr No. 1	30	3N	12W	503	...		22	131
	Laughlin No. 1	30	3N	12W	469	...		22	54
	Fyffe No. 7	1	3N	13W	520	...		16	86
	Ridgely No. 1	11	2N	12W	471	...		24	135
	Collison No. 2	27	2N	12W	423	...		33	150

TABLE 31—Concluded

County	Town or farm name and well number	Location Sec.	T.	R.	Altitude above sea level	Reference: Geol. Survey of Illinois Vol.	Page	Ill. State Geol. Survey Bull.	Page
					Feet				
Livingston....	Chatsworth......	...			...	VI	243	..	..
	Cullom..........	...			...	VIII	29	..	..
	Fairbury.........	...			...	VI	242	..	..
	Pontiac..........	...			...	VI	241	..	..
	Saunemin........	...			...	VIII	31	..	..
	Strawn..........	...			...	VIII	30	..	..
Macon........	Decatur..........	...			...	VIII	48	..	..
						VII	17	..	..
						VII	193	..	..
	Macon...........	1	15N	2E	727[a]	...		16	119
	Niantic..........	...			...	VII	19	..	..
Marion........	Iuka (Williams).	24	2N	3E	540[a]	...		16	78
	Iuka (Woodbridge)........	4	2N	4E	540[a]	...		16	79
McLean.......	Bloomington.....	...			...	IV	185	..	..
Piatt..........	Cerro Gordo.....	3	17N	4E	680[a]	...		16	121
Richland......	Claremont (5 miles S.)......		3N	14W	502	...		16	82
	Olney............	12	3N	10E	480[a]	VII	8	16	81
Vermilion[b]....	Sidell............	26	17N	13W	650[a]	...		16	124

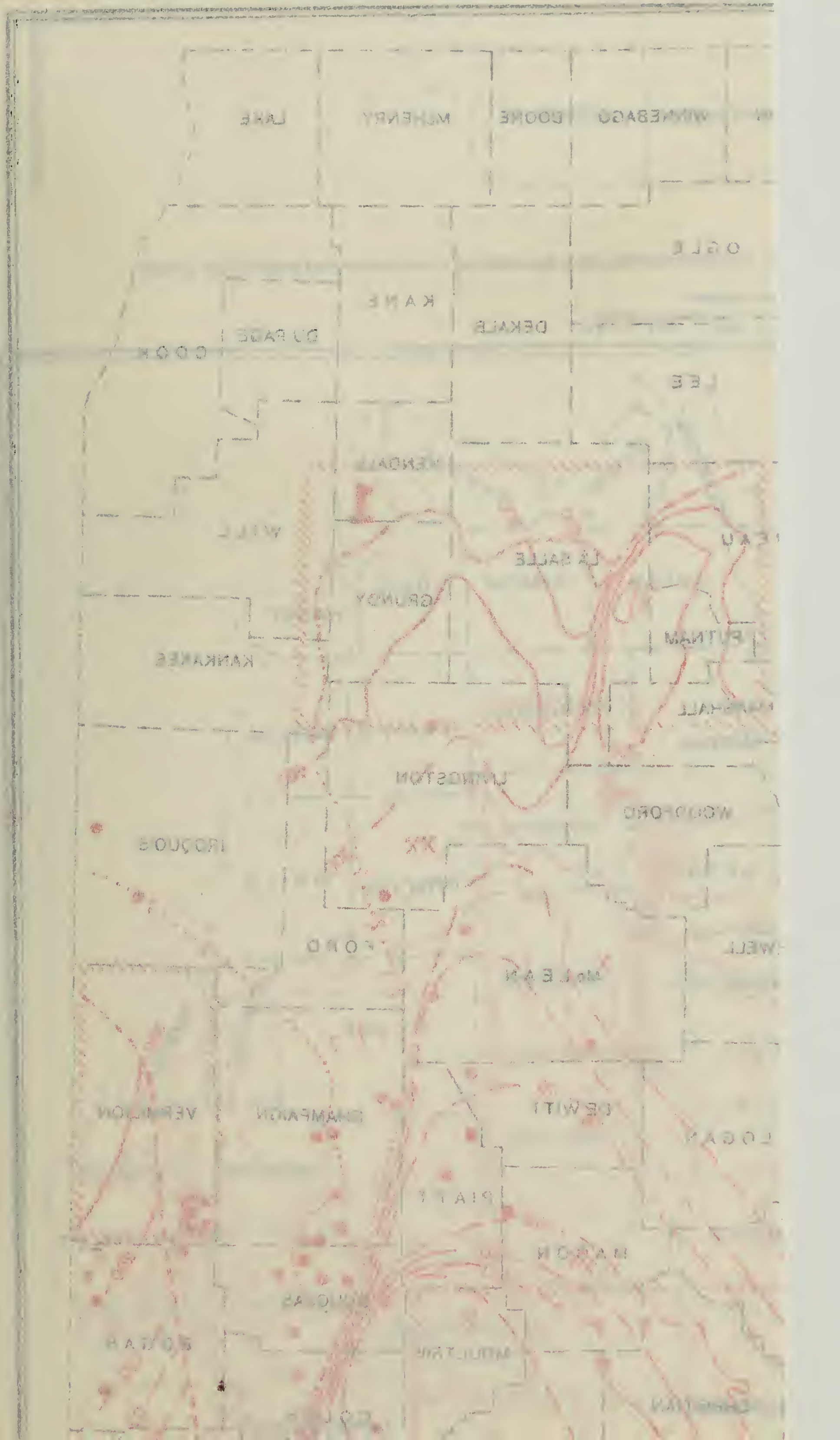
a Estimated.

b Records of borings within the areas described in the various bulletins of the Illinois Cooperative Mining Investigations in general not included.

INTERPRETATION OF THE STRUCTURE MAP OF THE PENNSYLVANIAN SYSTEM

PRELIMINARY STATEMENT

A number of features of interest are found on the structure map of the Pennsylvanian system to which special attention may well be directed These are: (1) The absence of Pennsylvanian strata along the crest of the anticline in Champaign and Douglas counties; (2) the apparent overlap of the Carbondale and McLeansboro formations beyond the boundary of the No. 2 coal basin in Edgar, Clark and possibly in Vermilion and Champaign counties; (3) the variations in the strength of the deformations as indicated by the undulations in the crest of the anticline; and (4) the variations in the depth of the trough paralleling the crest, producing a succession of deep basins and intervening saddles which lie opposite the undulations of the crest of the fold. These various features of the deformation will be considered in order.



(1) PRE-PENNSYLVANIAN INLIER IN CHAMPAIGN AND DOUGLAS COUNTIES

The map shows the outcrop of No. 2 coal passing south across the east side of Livingston County and thence swinging slightly to the west across Ford County whence it partially surrounds an area in Champaign and Douglas counties lying along the axis of the fold. Finally it swings off to the northeast near Paxton in Ford County crossing the southeast part of Iroquois County near the town of Milford. There is no definite evidence that the "Coal Measures" are absent under most of Ford County as indicated, but it is believed that if they are present they are probably thin and the absence of workable coal is strongly suspected. Chatsworth is known to be near the outcrop of No. 2 coal and at Strawn, a coal probably No. 2, lies at a depth of only about 110 feet. The fact that a preglacial valley extends northward through Champaign County together with the shallowness of the "Coal Measures" in adjacent parts of Livingston County, gives some basis for suspecting the absence of Pennsylvanian strata through the southern part of Ford County as well as along the crest of the anticline in Champaign and Douglas counties.

The absence of Pennsylvanian strata along the crest of the anticline is determined by wells at Mahomet, Champaign, and Pesotum in Champaign County, and at Tuscola and Camargo in Douglas County. In the records of none of these wells is there coal reported and the records of some of them indicate the entire absence of strata of Pennsylvanian age. The first indurated rock encountered varies in age from Upper Devonian black shale in the wells at Mahomet to Mississippian limestone in the wells in Douglas County (see Plate IV). The depth to the rock at various places in this area, its altitude and age are shown in the following table.

Table 32.—*Depth and altitude of the rock surface and the age of the bed rock at various places in Champaign and Douglas counties*

Location	Rock surface		Age of bed rock
	Depth	Altitude	
Champaign County	*Feet*	*Feet*	
Champaign	253	487[a]	Pennsylvanian (?)
Mahomet	329	380	Upper Devonian
Pesotum	300	420[a]	Mississippian (?) limestone
Douglas County			
Tuscola	294 ?	...	Upper Devonian (?)
Camargo	?	?	Upper Devonian at 570

[a] Estimated.

In view of the great depth of the pre-glacial valley in Champaign County it is apparent that the entire absence in places of Pennsylvanian strata across the anticline is largely due to erosion, and that the outcrop of the system can be only approximately indicated so long as the topography of the rock surface remains largely unknown. But even were only about 300 feet of Pennsylvanian strata present, instead of drift, this would represent a considerable thinning of the coal-bearing rocks as compared with their thickness in the trough west of the anticline.

From Tolono southward along the axis of the anticline the drift seems to be underlain by a series of sandy shales and sandstones overlying Devonian or Mississippian shale or limestone. These siliceous beds apparently do not contain coal seams, and their age is uncertain. In the "oil well" at Tolono,[1] these beds seem to begin at a depth of about 285 feet with their lower extension poorly defined. Similar beds are reported to be present in wells near Tuscola and Camargo. Their possible significance will be considered in a later paragraph.

The height of the pre-Pennsylvanian surface along this belt is specially noteworthy in view of the regional southward dip of all strata from the edge of the coal basin. The altitude of the Devonian shale at Mahomet is about 400 feet above sea level, only about 200 feet below the altitude of the base of the Pennsylvanian system along the crest of the anticline in the La Salle region. In view of this consideration and others to be presented in following paragraphs it does not seem improbable that the pre-Pennsylvanian surface stood sufficiently high along the axis of the anticline until possibly as late as early Carbondale time to prevent sedimentation upon it. It is thought that the anticline may have determined the position of an elongated island during early Pennsylvanian time, which later became gradually submerged as a result of continuous or periodic subsidence during Carbondale and McLeansboro deposition.

(2) THE AREA OF PENNSYLVANIAN OVERLAP IN VERMILION, EDGAR, CHAMPAIGN, AND DOUGLAS COUNTIES

Bordering the area wherein the Pennsylvanian strata are absent or largely eroded as described in preceding paragraphs and as shown on the map (Pl. VIII) the Pennsylvanian system extends with increasing thickness to the east, south, and west. The increase in thickness to the west is apparently very abrupt and its nature largely indeterminable. To the east, however, and south along the axis of the anticline, the thickening is sufficiently gradual so that even scattered drilling gives some indication of the nature of the change in the succession. Most noteworthy in this connection are changes toward the State line as described in the next paragraph.

[1] Ill. State Geol. Survey Bull. 16, p. 123, 1910.

Investigations have shown that in Vermilion County No. 6 coal dips *west* about 20 feet per mile between the Himrod mine, sec. 10, T. 18 N., R. 11 W., and Sidell.[1] The coal at the former place has an altitude of 575 feet and at the latter 225 feet above sea level. Drill records show that whereas the coal dips west in Vermilion County the pre-Pennsylvanian surface is approximately horizontal, effecting therefore a pinching out of the lower Pennsylvanian system in that direction. The edges of the pre-Pennsylvanian strata, however, are truncated by the surface upon which the Pennsylvanian rocks lie, since the older rocks dip to the east. For instance, the Devonian strata dip eastward from Pesotum to the State line from an altitude of about 400 feet above sea level to an altitude of about 300 feet below sea level. This structural dip of the pre-Pennsylvanian strata to a certain extent apparently effects a rise of the pre-Pennsylvanian surface toward the crest of the anticline, since this is about 300 feet higher at Pesotum than in the southwest part of Vermilion County. Since the Pennsylvanian strata pinch out below No. 6 coal in Vermilion County where the pre-Pennsylvanian surface is essentially horizontal, there is good reason for arguing for a continuation of such thinning still farther to the east against a rising surface.

The overlap or extension of No. 6 coal beyond the edge of the basin in which No. 2 coal was deposited seems to be established by the stratigraphic relations known to exist in Vermilion County as described above. That only one coal—a relatively thick one, probably correctly correlated as No. 6 or No. 7—is found west of Vermilion and Edgar counties, is indicated by scattered drilling and rumors of the occurrence of such a coal at various places in Champaign and Douglas counties. For instance, such a bed is reported to have been discovered at Urbana[2]; borings at Rantoul are said to have found at one place a nine-foot bed of coal at a depth of 120 feet, and the same seam was found at another place near by at a depth of 160 feet.[2] At Sidney 6 feet of coal are reported to have been found at a depth of 250 feet.[3] In Douglas County 7 feet of coal were reported found in a well on the Helm farm 2 miles west and 1 mile north of Murdock at a depth of 316 feet. On the Henson farm near Villa Grove (SE. cor. of the NW. ¼ sec. 11, T. 16 N., R. 9 E.) five feet of coal was struck at a depth of 225 feet, with red shale probably of pre-Pennsylvanian age at 570 feet. West of Oakland in sec. 8, T. 14 N., R. 10 E., 4 feet of

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[1] Kay, F. H., and White, K. D., Coal resources of District VIII (Danville): Ill. Coal Mining Investigations Bull. 14, Pl. II, 1915.

[2] Geol. Survey of Ill. Vol. IV, p. 274, 1870.

[3] Geol. Survey of Ill., Vol. VIII, p. 27, 1890.

coal was struck at a depth of 270 feet. The depth at which the thick coal is found in the various wells leaves a relatively small interval between this coal and the base of the Pennsylvanian system, so that it seems probable either that there has been elision of some of the lower part of the Pennsylvanian system as found farther east and also to the west of the anticline, or that a notable thinning of the constituent members of the formations has taken place. As further evidence of overlap, the presence of a considerable thickness of siliceous strata possibly of Pennsylvanian age lying across the position of the anticline in Douglas County may be cited. These possibly represent the shore phase of beds elsewhere represented by strata carrying coal and limestone.

The eastward thickening of the "Coal Measures" away from the anticline persists southward through Edgar County, as drill holes in Range 11 West commonly penetrate 500 to 600 feet of Pennsylvanian strata and numerous beds of coal, whereas a similar section seems to be absent in western Edgar County. The way in which the coals play out toward the west is indicated by data tabulated in Bulletin 14 of the Illinois Coal Mining Investigations[1] showing the drill records for the coal in Edgar County. The table shows that in several holes in Range 11 West as many as 9 coals have been penetrated, whereas in two holes in Range 13 West only 3 coals were penetrated in a depth of 540 feet. Other drilling seems to indicate a greater proportion of clastic material near the anticline than toward the Indiana line. It may be suggested that this development of sandstones and sandy shales along the anticline is possibly as effective in producing oil and gas reservoirs as is the deformation of the rocks, which seems to have been slight.

Southward along the anticline there is a thickening of the Pennsylvanian system similar to that which takes place to the east, and furthermore No. 2 coal as well as No. 6 is present in the section. Accordingly, in northern Crawford County the Pennsylvanian strata are coal bearing to a depth of nearly 900 feet, with No. 6 coal commonly at a depth between 500 and 600 feet and No. 2 coal about 300 feet lower. The base of the Pennsylvanian is reached at a depth of about 1,200 feet in northern Crawford County, whereas northward along the anticline in northern Clark County the base of the Pennsylvanian is reached at a depth of about 600 feet. It is believed that the considerable thickening that takes place in the Pennsylvanian rocks southward along the crest of the anticline is of a similar nature to that taking place eastward in Vermilion County as explained in a preceding paragraph, and that it indicates progressive

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[1] Kay, F. H. and White, K. D., Coal resources of District VIII (Danville): Ill. Coal Mining Investigations Bull. 14, p. 33, 1915.

overlap of Pennsylvanian strata upon the pre-Pennsylvanian surface which had been elevated along the anticline.

If overlap took place from the south and east it also probably took place from the west, but evidence of this is essentially lacking. There is some suggestion in the records of wells drilled near Mattoon and Charleston in Coles County that the interval between No. 6 coal and the base of the Pennsylvanian system is less than the interval the combined thickness of the Carbondale and Pottsville sediments commonly calls for. No. 6 coal lies at a great depth in the trough of the fold in Moultrie and Coles counties; for instance, the depth of the coal at Lovington is 900 feet, which is also about its depth at Mattoon. A drill record of a hole bored near Mattoon notes the presence of this coal and of a limestone, below a considerable thickness of sandstone and sandy shale underlying the coal, at a depth of 1,177 feet. There is a possibility that this limestone is of Mississippian age. A similar succession was met with in a drill hole located between Charleston and Mattoon which penetrated still deeper without finding any coal beds below a depth of 900 feet. The possible absence of No. 2 coal is therefore suggestive of overlap toward the anticline from the west also.

(3) UNDULATIONS IN THE CREST OF THE FOLD

The structure map shows three positions where conspicuous displacement has taken place across the anticline and two intervening positions of slight displacement. The strata have been more strongly folded in La Salle, Champaign, and in Lawrence counties, and less strongly folded in Livingston and Crawford counties.

The weak structure in Livingston County is apparent from the approximate horizontal position of No. 2 coal across the anticline. This relationship will be discussed further in considering certain features of the trough west of the fold. The evidence of weakness of the structure in Cumberland and Crawford counties is also determined by the altitude of No. 2 coal either side of the anticline. In Crawford County No. 6 coal lies nearly horizontal at about sea level. This is only about 100 feet higher than its altitude in southern Shelby County, and apparently indicates a diminution in the strength of the folding.

The position of the elevated portions along the crest of the fold has been indicated. The height of the deformation can readily be determined in La Salle County from outcrops along Illinois River. The general structural features of that region have already been described at length. The determination of the full extent of Pennsylvanian deformation in Champaign and Douglas counties is not possible because of the absence of the "Coal Measures" across the axis of the fold. The difference in the

altitude of the bed rock along the anticline as at Mahomet and of No. 2 coal at Monticello is at least as much as 500 to 550 feet, a figure which represents the minimum amount of deformation of Pennsylvanian strata possible to postulate, provided No. 2 coal was ever deposited across the anticline in this area. If overlap took place and the deformation is to be measured by comparative altitudes of No. 6 coal, and the coal underlying parts of Champaign County is conceded to lie at about the horizon of No. 6 coal, then the displacement amounts to about 400 to 450 feet. It is not improbable that in this area just as in the La Salle region some deformation took place during Carbondale time, that is, between the deposition of No. 2 and No. 6 coals so that the structure of No. 6 coal is not a true measure of the total amount of deformation during Pennsylvanian time. The structure in Lawrence County can be better described in connection with the description of the structure of the trough west of the fold which is to follow.

(4) VARIATIONS IN THE DEPTH OF THE TROUGH

The trough west of the anticline is characterized by irregularities in depth which parallel the undulations of the crest line of the fold. These irregularities produce three deep basins and two intermediate saddles. The basins lie in (1) La Salle, (2) Shelby and Moultrie, and (3) Wayne counties, and the saddles in (1) Woodford and (2) Shelby and Cumberland counties.

The basin in the La Salle region has been adequately described and delineated by a structure map in Illinois Coal Mining Investigations Bulletin 10 which describes the geology of the Pennsylvanian strata in the Longwall District. The basin is very definitely indicated by the dip of No. 2 coal toward a center which lies about at Oglesby. It reaches a depth more than 150 feet below the height of the saddle between Minonk and Bloomington.

The characteristics of the basin in Moultrie and Shelby counties have been less definitely determined than those of the one to the north. The central part of this basin seems to include the area in which the towns of Shelbyville, Lovington, Bourbon, and Mattoon are located, that is nearly all of Moultrie and parts of Shelby and Coles counties. At Lovington No. 6 coal lies at a depth of 900 feet, or about 220 feet below sea level; at Shelbyville the same coal is 215 feet, at Mattoon about 200 feet and near Bourbon about 100 feet below sea level. This basin shallows rather rapidly to the north and northwest as No. 6 coal is about 150 feet above sea level at Decatur, and probably about 40 feet above sea level near Cerro Gordo. The rise along the trough of the fold northward toward Colfax in northeastern McLean County is relatively gentle. At this latter place a five-foot bed of coal which is probably

either No. 5, 6, or 7 lies about 343 feet above sea level. These three coals are closely associated in the northern part of the State, so that the figure given indicates at least the approximate altitude of No. 6 coal.

There has been practically no exploration of the Pennsylvanian strata below No. 6 coal in the Moultrie County basin, so that the structure as drawn, indicating No. 2 coal as lying about 300 feet below No. 6 coal or about 500 feet below sea level has not been established by drilling. Mention has already been made of the possibility supported by the results of drilling near Mattoon and Charleston, that near the anticline the interval between No. 6 coal and the Mississippian rocks may be much less than that of the combined thickness of the Carbondale and Pottsville formations in the central part of the State commonly calls for. Accordingly, it may be that the Pottsville formation and even No. 2 coal wedge out against the pre-Pennsylvanian strata as they rise toward the anticline.

At Saybrook in eastern McLean County a 3-foot bed of coal lies at an altitude of about 200 feet above sea level. It is reported to be associated with black slate or cannel coal, which is suggestive of correlation with No. 5 coal and with the seam mined at Colfax. If this correlation is correct and No. 2 coal is present in the section below, its altitude at Saybrook is about sea level. At Farmer City a coal correlated with No. 2 lies at an altitude of about 50 feet above sea level, and a coal is reported at Deland at about the same altitude. In view of these facts it appears that there may be a small basin similar to the others found along the trough west of the anticline the center of which is in eastern McLean County. If such a basin exists the saddle between it and the Moultrie County basin lies between Deland and Monticello where No. 2 coal has an altitude of about 50 feet above sea level.

The existence of the Wayne County basin is indicated by drilling at Olney, Richland County, Sailor Springs, Clay County and near Goodland (T. 2 S., R. 6 E.), Wayne County. At Olney, No. 6 coal is thought to lie at a depth of 1,160 feet, that is, 660 feet below sea level, and if No. 2 coal is present 300 feet below, it lies nearly 1,000 feet below sea level.[1] This is approximately the altitude determined for this coal in a boring in southern Wayne County. In the Sailor Springs well the horizon of No. 6 coal is thought to be at a depth of about 1,010 feet, and the altitude of No. 2 coal about the same as at Olney.

The amount of displacement of No. 6 and No. 2 coals across the anticline in Lawrence County may be determined by comparing the altitude of the coal as determined in Lawrence County with the altitude of the coal in Wayne County. At Lawrenceville, No. 6 coal lies about 80

[1] Blatchley, R. S., Illinois oil resources: Ill. State Geol. Surv. Bull. 16, p. 88, 1910.

feet below sea level and No. 2 coal is estimated to lie about 320 feet lower. In discussing the structure of the No. 6 coal in the Sumner and Vincennes quadrangles, Savage and Blatchley[1] state as follows:

"In a boring near the middle of sec. 21, T. 5 N., R. 11 W., three miles southeast of Flat Rock, the Herrin coal (No. 6) was encountered at an altitude of about 41 feet below sea level. In another boring 13 miles south of the latter and 3½ miles south of Lawrenceville in the NW. ¼ sec. 25, T. 3 N., R. 12 W., this coal was reached at an elevation 39 feet lower, or 80 feet below sea level, indicating a general southward dip of the strata between these points of about 3 feet to the mile.

"In a boring about 5 miles west and 5 miles north of the test holes last mentioned, near the middle of sec. 31, T. 4 N., R. 12 W., the Herrin coal was found at an altitude of about 10 feet above sea level, indicating a rise of the strata toward the north and west between these points. Rocks outcropping at the surface in the Sumner and Vincennes quadrangles indicate that the strata are more or less undulating, but lie nearly level across the north end of the area, and that they have a general southward dip of a few feet per mile, as above indicated."[2]

The difference in the altitude of the No. 6 coal across the anticline accordingly appears to be about 600 feet. Surface rocks show no indication of such a dip, as the same formation has been identified by Savage outcropping at Olney and at Lawrenceville, with an altitude at Olney somewhat higher than that at Lawrenceville. This lack of parallelism between the upper and lower members of the Pennsylvanian system is to be explained by assuming a great thickening of the beds as they enter the trough or by an unconformity. In either case movement along the fold must essentially have ceased before the end of Pennsylvanian time.

Further evidence of lack of conformity in the structure of the upper and lower Pennsylvanian beds is found in the distribution of a *Fusulina*-bearing limestone in Coles County. Along Embarrass River from Greenup north to Charleston there are reported numerous exposures of this limestone, which is stratigraphically high in the Pennsylvanian system of Illinois. The Embarrass River runs across the supposed position of the axis of the anticline where this limestone is found, and if the entire thickness of the Pennsylvanian system were effected by the deformation, a succession of strata would be looked for and not a continuation of the same bed at approximately the same altitude. Except for a single exposure of sandstone in sec. 25, T. 12 N., R. 9 E., near Charleston, there is no evidence of unusual structural conditions affecting the outcropping rocks in Coles County.

[1] Savage, T. E. and Blatchley, R. S., Geology and mineral resources of the Sumner and Vincennes quadrangles: Unpublished manuscript in the files of the State Geological Survey.

[2] See also data concerning the depth of coal in Crawford and Lawrence counties shown in Plate III.

The existence of the saddles between the basins is essentially established by the evidence which establishes the existence of the basin. The shallowing of the basin in Woodford and western Livingston counties is indicated by the northward dip of the coal from Minonk and its southward dip from northern McLean County. The slight difference in altitude of the coal on the two sides of the main fold where the saddle is highest is indicated by the following tabulated data.

Table 33.—*Depth and altitude of No. 2 coal at several localities in Woodford, McLean, and Livingston counties*

Location	East or west side of anticline	Depth to coal	Altitude of coal
Livingston County		*Feet*	*Feet*
Fairbury	East	571	109±
Pontiac	East	368	272±
McLean County			
Chenoa	West	Not below 478	242±
Woodford County			
Eureka	West	500 Est.	257±
Minonk	West	537	214

The northward dip of the strata from this saddle is born out by the outcrops along Illinois River northward from Chillicothe. At this place No. 6 coal is well above the river, but there is a persistent dip north which brings it nearly to river level a little north of Sparland and to well below river level at Bureau. There is a strong suggestion of an east-west axis of uplift crossing a large portion of the coal basin at the latitude of this saddle.

The saddle lying between the Moultrie and Wayne County basins extends from east to west across the southern part of Shelby County. There are two drill holes in the southeastern part of the county in which No. 6 coal is higher than at Shelbyville. In sec. 24, T. 10 N., R. 4 E., the coal is about 70 feet higher than at Shelbyville,[1] although if regular dips prevailed it would be somewhat lower. About 8½ miles east of the last mentioned hole there is another in which the horizon of No. 6 coal is 35 feet higher than in the first.

[1] Kay, F. H., Coal resources of District VII; Ill. Coal Mining Investigations Bull. 11, p. 211, 1915.

The altitude of the coal on the two sides of the anticline at the position of the saddle in Shelby County is not greatly different. In northern Crawford County No. 2 coal lies about 300 feet below sea level (see Plate III) which is approximately its altitude in southeast Shelby County. It seems probable that the structure across the lines of the anticline at the position of this shallow place in the trough is very similar to the structure across the fold in Woodford and southern Livingston counties.

CHAPTER V—INTERPRETATIVE STUDIES

Preliminary Statement

The description of the structure of the anticline has been presented, not as evidence in support of a theory, but primarily with the purpose of assembling the available information concerning the form and position of the anticline. In order to make the description something more than a catalog of structural details some attempt to organize the material seems called for. Accordingly the following interpretative studies are presented.

The interpretation of the structure described is undertaken from two points of view. The deformative movements are considered first as historical events, and their order and relationship in time are suggested. Secondly the form, position, and development of the deformation are considered from the view-point of earth dynamics. Other points of view are conceivable, especially those which concern the stratigraphy and paleogeography, but the data bearing on these latter have not been assembled.

History of the Deformation as Determined by Structural Relationships

In considering the development of the structures as an historical event or series of events, a knowledge of the structural relationships of the several formations involved is of the greatest importance. Without more complete stratigraphic data than have been presented, the story is incomplete, but the structural relationships as described involve certain conclusions in regard to the order of events which will limit hypotheses if ever the stratigraphic problem is considered more exclusively. The relationships determined that have bearing on the problem are:

1. Structural unconformity between the St. Peter sandstone and the "Lower Magnesian" limestone.
2. Structural unconformity at the base of the Chester group.
3. Structural unconformity at the base of the Pennsylvanian system.
4. Structural unconformities within the Pennsylvanian system.
    a. Below No. 2 coal.
    b. Between coals No. 2 and No. 7 and between No. 2 coal and the La Salle limestone. These two may actually be one.
    c. Non-parallelism of the upper and lower members of the Pennsylvanian system in southeastern Illinois.

5. The structural relationship of the La Salle limestone and No. 2 coal, especially as concerns the relation between the strike of the limestone and the strike of the line of increased dip of the coal.

6. The distribution of the La Salle limestone in relation to the anticline.

The historical significance of these various structural relationships may be briefly summarized without argument.

It is probable that movement took place after "Lower Magnesian" time and before the deposition of the St. Peter sandstone. It is not determined, however, that the deformation was restricted to the axis of uplift along the La Salle anticline as it has been later developed. The deformation of the older formations, on the other hand, seems to have been general rather than local, producing warping and buckling not paralleling the main axis of the larger and later deformation.

Although stratigraphic unconformities are known to exist between formations included in the great series and systems between the "Lower Magnesian" limestone and the Pennsylvanian "Coal Measures", the nature of the structural relationships is for the most part a stratigraphic rather than a structural problem, involving the study of the distribution and extent of biologic and lithologic provinces in relation to the anticline. Such structural data as are available concerning these intermediate formations indicate the probability of a slight structural unconformity between the Platteville limestone and the St. Peter sandstone, and between the Maquoketa formation of the Richmond group and the overlying rocks of the Silurian system. The amount of movement at these times seems to have been small, and seems to have been positive rather than negative, but the outcrops showing these structural relations are all on the east side of the axis or along the crest of the anticline, and possibly are not present on the west side. Between the Silurian and Mississippian systems, however, there are significant differences in structure, and differences of nearly the same order and character are apparently present between the lower Mississippian groups of limestone formations and the Chester group, composed largely of clastic formations.

The north line of the Chester embayment in Illinois is shown on the accompanying map (Pl. IX), with figures showing the thickness of the group near the boundary. These figures indicate a very rapid thickening near the edge of the basin, and the relationships are such as to compel the belief that structural unconformity exists between the pre-Chester and Chester strata. This information anticipates stratigraphic studies, but it has seemingly such an important bearing on the development of the structure that it cannot well be passed over without some comment.

In a paper read before Section E of the American Association for the Advancement of Science, December 26, 1916, Professor Stuart Weller described the pattern of the Chester embayment as compared with the pattern of the older embayments as follows:

"The geographic pattern produced [by the Chester embayment] was quite different from that of the older epochs. During the earlier times the sea generally quite surrounded Ozarkia, at periods of maximum advance, or even submerged that land during a portion of that time. Subsequent to Ste. Genevieve time the Chester sea, spreading away to the south, extended northward only to the southern shores of Ozarkia and Cincinnatia. So far as surface outcrops are concerned there is no evidence of the extension of the Chester sea beyond St. Louis, but the sediments deposited in the embayment may extend farther north in a northeast direction beneath the Pennsylvanian. It can be stated with assurance, however, that the embayment never reached away to the north and northwest as the earlier embayments had done.

"The type of sediments deposited in the Chester embayment are wholly different from those of earlier periods. The earlier formations are almost entirely calcareous, with minor amounts of shale in Keokuk, Warsaw, and higher members and very subordinate amounts of arenaceous material in the Ste. Genevieve. The Chester sediments include important limestones, most of which are impure and highly argillaceous, many beds of shale and a number of massive sandstone formations."

It is believed that a structure map based upon some recognizable and widespread Chester formation, or stratum, would furnish definite proof that the structure of these rocks differs materially from the structure of the St. Peter sandstone and that of No. 2 coal as presented in this description. In the only part of the State where the structure of the Chester can be shown, namely, in Lawrence County, it is impossible to indicate the structure of the St. Peter sandstone because of lack of data, hence the comparison suggested is impossible. However, that a structural unconformity exists in this region between the Chester and pre-Chester formations is indicated by the widening interval between the McClosky (Ste. Genevieve) formation and the Kirkwood and Tracy (Chester) sandstones. This relationship is described by T. E. Savage in an unpublished manuscript, previously cited, describing the geology and mineral resources of Hardinville quadrangle.

In view of the existence of this important unconformity between Chester and pre-Chester formations it is apparent that important movements must have taken place just before, or during, Chester sedimentation. It is quite probable inasmuch as numerous unconformable contacts are found between successive members of the Chester group that movements were numerous during Chester time, causing great variation from time to time in the size, shape, and depth of the basin.

A conspicuous structural unconformity separates the Pennsylvanian strata from strata of pre-Pennsylvanian age. In exposures along the

northern edge of the coal basin this unconformity is between rocks of Ordovician and Pennsylvanian age on the crest of the fold, and between Silurian or even Devonian and Pennsylvanian strata on the flanks of the fold. At La Salle outcrops show only that movement took place after Galena time and prior to Pennsylvanian time. From the fact that Silurian and probably Devonian strata of average thickness are found in the trough immediately adjacent to the anticline on the west, it may be inferred that the deformation which caused the unconformity between the Ordovician and Pennsylvanian strata in exposures at Split Rock, Deer Park, Lowell and elsewhere took place between Devonian and Pennsylvanian time.

As the anticline is traced south through Livingston, Champaign, Douglas, and other counties to Lawrence county, younger and younger formations come in on the crest of the fold below the Pennsylvanian strata as found at La Salle, with Chester rocks finally underlying the Pennsylvanian in Crawford and Lawrence counties. The structure of the Pennsylvanian and pre-Pennsylvanian strata is unconformable lengthwise of the deformation, and the most significant deformation in the section seems to be this one below the base of the Pennsylvanian system. It does not appear, however, that the structural discordance between the Pennsylvanian and Chester strata is as great as that between the Pennsylvanian and Ordovician formations of northern Illinois, probably because some of the movement causing the Pennsylvanian-Ordovician unconformity took place previous to or during Chester time.

From the structural relationships as summarized, therefore, it seems necessary to conclude that the principal pre-Pennsylvanian deformation along the La Salle anticline is a result of late Paleozoic movement the greater part of which has taken place since the end of early Mississippian or Ste. Genevieve time. Part of this movement seems to be of Chester age, but a large part is post-Chester although pre-Pennsylvanian or at least pre-Carbondale.

Well borings indicate that this pre-Pennsylvanian unconformity is probably most divergent in Champaign and Douglas counties, since here apparently the deformation was of sufficient strength to produce a surface which was not reduced to sea level or deposition level during Pottsville and early Carbondale time. The relationships in these counties may signify the possible continuation of the upward movement during early Pennsylvanian time rather than the especially high elevation at an earlier date.

The deformative movements producing structural unconformities within the Pennsylvanian system indicate that movements took place during rather than after this period. Near La Salle there are evidences of

structural discordance between Carbondale and Pottsville sediments, as shown by the outcrops at Split Rock, and between No. 2 and No. 7 coals, as indicated by the difference in the interval between these two horizons on the two sides of the anticline. Lack of parallelism of No. 2 coal and the La Salle limestone also exists, but whether or not all discordance in structure that exists in this interval is due to the unconformity between No. 2 and No. 7 coals is not known. A curious parallelism as between No. 2 coal and the La Salle limestone may have historical significance. Along a line approximately parallel to the strike of the La Salle limestone and approximately below its outcrop the coal changes its rate of dip 10 degrees or more and its direction of strike to correspond to that of the La Salle limestone. The relationships are such as to suggest that deformation of the limestone and the deformation of the coal along the line of increased dip are synchronous.

The history of the deformation in La Salle County, as shown by outcrops and drillings is apparently about as follows:

(1) Deformation of the "Lower Magnesian". This deformation manifests itself in structural irregularities of a small scale, such as small folds in the Shakopee member of the "Lower Magnesian" limestone which apparently do not pass up into the overlying St. Peter sandstone. Deformations of a larger order such as would be indicated by the irregularity in thickness and distribution of the Shakopee dolomite over a large area are not considered, as such a consideration would involve the introduction of a greater amount of stratigraphic evidence than this report otherwise calls for. It may be stated that the nature and extent of this pre-St. Peter deformation has not been determined with as great care, or with as great attention to details, as has been given to the later deformations and it is possible that further field investigations, specially in the Dixon region, will arrive at a more definite interpretation of the stratigraphic and structural relations between the "Lower Magnesian" limestone and the overlying sandstone.

(2) Slight deformation of the St. Peter sandstone causing an unconformity between it and the overlying Platteville dolomite. This deformation seems to have been in the nature of a gentle up-warping along the axis of the anticline, across the top and along the flanks of which the lower beds of the Platteville formation failed of deposition.

(3) Deformation some time after Silurian and probably after Devonian deposition. This deformation is the major deformation prior to Pennsylvanian time and probably took place, judging from evidence observed elsewhere, as late as late Mississippian time. The line of deformation seems to have been at the position of the increased inclination of the St. Peter sandstone and Platteville dolomite or limestone

as displayed at Deer Park and at other places along the anticline. The strata probably dipped eastward and westward from this line.

(4) Deformation possibly shortly before the deposition of No. 2 coal, causing the unconformity near the base of the "Coal Measures" as displayed at Split Rock.

(5) Deformation after the deposition of No. 2 coal and before the deposition of No. 7 coal. This deformation apparently took place along a line farther east than the axis of the earlier deformation, and there apparently was no bending at the position of earlier folding. It is possible that uplift along this second axis was continuous at intervals during most of Carbondale and McLeansboro time. It is possible, however, that its occurrence is indicated by the deposition of a massive sandstone, the Vermilionville, lying just below No. 7 coal in many places adjacent to the anticline. Additional stratigraphic studies are necessary in order to bear out the possibility of this relationship.

(6) Deformation after or during the deposition of the La Salle limestone, apparently along a line west of previous deformation and marked by the position of the line of increased dip of No. 2 coal in Black Hollow mine. That this deformation may have taken place while the limestone was being deposited is suggested by the relationship between its distribution and the position of the fold.

Evidence that the Pennsylvanian deformation was essentially accomplished within Pennsylvanian time is at hand in southern Illinois. In Coles, Cumberland, Jasper, and Lawrence counties outcropping Pennsylvanian strata are apparently horizontal, at least there is no belt of strongly folded rocks such as may be observed in La Salle County. The lower Pennsylvanian strata, however, have been folded, as indicated by results of drilling. If this relationship exists, it is hence necessary to believe, that folding in this part of the State came to an end before the close of Pennsylvanian deposition. The highest formation in the La Salle region is probably considerably below outcropping strata in the counties mentioned in the southeastern part of the State. Accordingly it is possible that the later deformation in the La Salle region took place also entirely within Pennsylvanian time, and that it is not a post-Pennsylvanian deformation as has been commonly stated.

Stratigraphic Problems

Before leaving the historical interpretation of the structure it will be well to indicate some of the stratigraphic problems that the structural studies have suggested as concerning the history of the deformation. These are:

1. (a) The variation in thickness and lithology of the "Lower Magnesian" limestone. The formation is apparently thicker near and

west of the anticline than it is to the east. (b) The distribution of the different members of the "Lower Magnesian" limestone, especially the Shakopee dolomite and the New Richmond sandstone. The latter is found in a large area lying across the anticline.

2. The nature and amount of unconformity existing between the St. Peter sandstone and the Platteville dolomite; the irregularity between these two formations produces the local elision of what seems to be the "quarry" bed section of the Platteville of southwestern Wisconsin, or the "lower buff" beds of the Beloit section.

3. Preliminary paleontological investigations by T. E. Savage have revealed the probability of a faunal barrier between a province of Richmond strata in eastern Illinois and Indiana and another province in western Illinois. There is also some indication of a westward thinning of the formation on the east side of the La Salle anticline. Further investigation may prove beyond question that there was deformation along the fold between Middle Ordovician and early Silurian time, possibly at the time of the deformations in Ohio, Kentucky, and Tennessee.

4. Investigations concerning the relation of the faunal provinces of the Alexandrian to the anticline.

5. The structural and stratigraphic basis for the Kankakee arch of paleontologists and paleogeographers, and its relation to the La Salle anticline, with which it apparently lacks structural agreement.

6. The structure and stratigraphy of the Chester, with the possibility of making a structure map based upon the altitude of a traceable formation which will show the nature of the unconformity between it and overlying and underlying formations.

7. Stratigraphic problems of the "Coal Measures" that may have a bearing on the history of the anticline are numerous; a few may be suggested as follows:

   a. Distribution of No. 2 coal around the barren area in Champaign and Douglas counties.
   b. Investigation of the apparent relationship of the deformation to the distribution of No. 6 coal.
   c. Distribution and origin of the Vermilionville sandstone in relation to the anticline.
   d. The relation of the northern Illinois and the northern Indiana portions of the Eastern Interior coal basin to the barren area in Champaign and Douglas counties.

Some Considerations Concerning the Dynamics of the Deformation

The circumstances under which the movements have taken place, which may be called the dynamics of the deformation, can be determined

within rather broad limits. Such determinations are based upon conclusions reached in the historical resumé just preceding and also upon field observation and drilling.

If the history of the deformation as interpreted from the structural relationships is correct, then it seems probable that the forces which produced subsidence of the Chester and Pennsylvanian basins also produced the deformation of the La Salle anticline. It seems probable also that these forces were of the same ultimate origin. Of the contributing causes of the two movements, the most effective seem to have been those which produced subsidence, since a much larger mass was involved in subsidence than in folding, and since the mass involved in the folding was also included in that involved in subsidence. It may be questioned, therefore, whether the thrusts which produced the folding may not have had their origin in the crustal shortening accompanying subsidence rather than in the fundamental adjustments which made subsidence necessary.

Evaluation of the amount of shortening possible by subsidence indicates that it is probably only one-tenth to one-twelfth of the actual shortening that was accomplished by the folding. The greatest possible amount of crustal shortening resulting from subsidence across the coal basin is about 340 feet. This figure is determined by assuming (1) that the basin lies between Lat. 87° W. in Montgomery County, Indiana, and Lat. 91° W. in Hancock County, Illinois, which is approximately 2° 1′ 48″ of curvature or a distance of 209.124 miles, and (2) that by the subsidence all curvature is eliminated. Elimination of curvature across an arc of this length entail a maximum subsidence at the mid-point of the arc of 1.4 miles. Under the most favorable interpretation of the nature of the structure before subsidence the actual amount of depression in the central part of the basin along the parallel indicated is only about ⅙ of that necessary to the elimination of all curvature and production of the maximum amount of shortening of about 340 feet. As the actual shortening along the anticline is between 500 and 1,000 feet it seems improbable, therefore, that subsidence alone was a competent source of the thrusts which produced the La Salle anticline, though it may have been a minor contributory cause of the folding.

A complete analysis of the causes which produced the La Salle anticline does not lie within the province of this discussion, and it is doubtful whether with the information yet available such an analysis should be attempted. However, it is believed that sufficient emphasis has been placed upon what is believed to be a fundamental relation between the subsidence of the Chester and Pennsylvanian basins and the development of the La Salle anticline to modify any hypothesis which may be attempted concerning the origin of either structure.

The position of the anticline, together with the persistence in direction of alignment, is strongly suggestive of an initial line of weakness at the position of the fold which localized the response to thrust. This line of initial weakness is possibly due to a concealed fault line which may be present in the deeply buried rocks, or it may be due to an initial slope of deposition. Stratigraphic studies will possibly show that the formations below the "Lower Magnesian" are distributed in respect to north and south lines of deformation[1], and accordingly the position of these formations may control later deformation.

"The general occurrence of this glauconiferous zone above the Jordan in the deep wells of northern Illinois is of great interest to me. It also is a source of much satisfaction, because it corroborates the paleogeographic early Ozarkian map I prepared somewhat more than a year ago. On this map I showed the early Ozarkian seas as invading in baylike form from the south through Illinois, and as limited on the east by the Kankakee axis. The western shore of the bay was and is yet doubtful, though I was inclined to draw it to the east of the main N.-S. Ozark axis. At its northern end I drew the bay as broken into small or rather narrow inlets extending 50 to 100 miles or more into Wisconsin. These extensions were to account for the streaky occurrence or linear arrangement of the Mendota dolomite. That this arrangement is as originally deposited is strongly indicated by the more general distribution of the upper (Madison) member of the Lower Ozarkian in Wisconsin."

Furthermore, the offset of the structure in Lawrence and Crawford counties, the folds diverging from the main axis, seems to indicate a playing out of the directing factor to the south, which, if the direction of the fold is controlled by faulting, might indicate a splitting off of minor faults such as commonly occur in fault zones.

CONCLUSION

In conclusion it may again be stated, at the risk of much repetition, that the preceding pages concern primarily a description of the form and position of the anticline, with brief attempt to interpret the facts assembled from an historical and from a dynamic point of view. By no means all problems involved are considered, and especially are many of the stratigraphic questions either unconsidered or only hinted at. But the stratigraphic and structural problems are not all. The physiographic aspects of the anticline present numerous interesting considerations, such as the relation of the anticline to glaciation; and the interpretation of certain interesting drainage adjustments of streams crossing the belt of steeply inclined strata. There is also apparently some possible relation between the anticline and the distribution of areas of dolomitization of the Platteville limestone. Accordingly, therefore, many considerations other than that of the structural features of the anticline remain as subjects for further investigations.

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[1] Letter from E. O. Ulrich to F. W. DeWolf, March 2, 1916.

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